TECHNICAL SPECIFICATION

FOR

SHIP'S SERVICE GENERATOR DIESEL ENGINE

Retrofit Application

FOR THE

FFG 7 CLASS SHIPS

Naval Surface Warfare Center, Carderock Division
Ship Systems Engineering Station
Philadelphia, PA, 19112

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

1 EQUIPMENT

1.1 Scope This specification establishes the performance technical,, and test requirements for a diesel engine to replace the existing engine in a ship's service generator set as listed herein, all assemblies, sub-assemblies and components identified herein, or required for proper operation of the equipment, shall be provided. The government will conduct the shipboard installations of the engines provided.

2 APPLICABLE DOCUMENTS

2.1 Government Documents

SPECIFICATION

Military

MIL-S-901D	Shock Tests, H.I. (High-Impact) Shipboard Machinery, Equipment, and Systems
MIL-E-2036	Enclosure for Electric and Electronic Equipment
MIL-G-21410A	Governor Systems: Speed and Load Sensing
MIL-C-5015	Connector, Electrical, Circular Threaded, AN Type, General Specification for
MIL-PRF-2104	Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service
MIL-T-15377	Temperature Monitor Equipment, Naval Shipboard
MIL-STD-1399	Interface Standard for Shipboard System
MIL-F-16884	Fuel, Naval Distillate
MIL-T-5624	JP-5 (Operational Test only)
MIL-T-24270	Thermowells for Thermometers and Electrical Temperature Sensors; General Specification for

Military (Con't)

MIL-V-24578	Valves, Globe, Pressure Instrument, Stem Test Connection, Union End
MIL-STD-167-1	Mechanical Vibrations of Shipboard Equipment (Type – Internally Excited)
MIL-STD-167-2	Mechanical Vibrations of Shipboard Equipment (Reciprocating Machinery and Propulsion System and Shafting) Types III, IV, and V
MIL-STD-108	Definitions of and Basic Requirements for Enclosures for Electric and Electronic Equipment
MIL-STD-178	Definitions applicable to Speed-Governing of Electric Generator Sets
MIL-STD-461	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
MIL-STD-777E	Schedule of Piping,Valves,Fittings, And Associated Piping Components for Naval Surface Ships
S6430-AE-TED-010	NAVSEA Technical Directive for Piping Devices and Flexible Hose Assemblies
S9074-AR-GIB-010/278	NAVSEA Technical Directive for Requirements for Fabrication, Welding, Inspection and Repair for Machinery, Piping, and Pressure Vessels

CODE OF FEDERAL REGULATIONS

30CFRS18.65	Cover Flammability Test MSHA (Old ASTM D 1692) Commercial Marine – All Sizes

2.2 Commercial Documents

AMERICAN SOCIETY FOR TESTING AND MATERIAL

ASTM B 369	Standard Specification for Copper-Nickel Alloy Castings
ASTM D 92	Standard Test Method for Flash and Fire Points by Cleveland Open Cup (AASHTO No. T 48) E1
ASTM D 93	Standard Test Method for Flash Point by Pensky-Martens Closed Tester (AASHTO No. T 73) (British Standard 2839) E1
ASTM D 189	Standard Test Method for Conradson Carbon Residue of Petroleum Products (British Standard 4380)
ASTM D 240	Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (R 1980)
ASTM D 445	Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity) (British Standard 4708)
ASTM D 482	Standard Test Method for Ash From Petroleum Products (IP 4/81) (British Standard 4450) E1
ASTM D 524	Standard Test Method for Ramsbottom Carbon Residue of Petroleum Products (British Standard (IP 14/82)

ASTM D 874	Standard Test Method for Sulfated Ash From Lubricating Oils and Additives (British Standard 4716)
ASTM D 893	Standard Test Method for Insolubles in Used Lubricating Oil
ASTM D 1744	Standard Test Method for Water in Liquid Petroleum Products by Karl Fischer Reagent
ASTM D 2622	Standard Test Method for Sulfur in Petroleum Products (X-Ray Spectrometry) E1
ASTM D 2896	Standard Test Method for Base Number of Petroleum Products by Potentiometric Perchloric Acid Titration
ASTM D 4176	Standard Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)
ASTM D 4294	Standard Test Method for Sulfur in Petroleum Products by Energy-Dispersive X-Ray Fluorescence Spectroscopy
ASTM D 1796	Standard Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure) (R 1990) (API MPMS Chapter 10.6) (IP 75/82) (British Standard 2882)

SOCIETY OF AUTOMOTIVE ENGINEERS

SAE J1349	Engine Power Test Code, Spark Ignition and Compression Ignition, Net,Power,Rating,,Standard.,(DOD adopted) Except Marine Diesel
SAE J1926	Straight O-Ring

3 DESIGN REQUIREMENTS

.3.1 Item Definition The diesel engine shall be directly coupled to a Government Furnished Generator at the flywheel end of the crankshaft and coupled to a Government Furnished Starting Air Compressor (SAC) at the other end of the crankshaft. The diesel engine shall be rated at a minimum of 1425 bhp at 1800 rpm for continuous operation. The engine shall also be capable of providing 110% overload capacity for one hour out of twelve. Engine crankshaft rotation shall be counterclockwise as viewed from the main drive end (flywheel end).

3.1.1 Interface Definition The engine shall interface with the 1000 kW Kato generator (Kato Model 099-00056-03) and Garrett Airesearch, Model No. 681950-1-1 (NAVSEA Dwg. 581786) starting air compressor, (rated power 695 HP) ship's piping electrical interface connections, the penetrations through enclosures for access to those connections, and electrical interface signals listed in Table I. Drawings depicted by Figures 1 through 13 shall be used to define the piping, electrical, and structural interface. Deviations for these interfaces shall be mutually agreed upon between the Government and Contractor.

This page left intentionally blank

Table I
SIGNAL INTERFACES

Item	Name	Per Engine Quantity	Signal Type	Notes	Identified As
1	Magnetic Speed Pickup	1	***	One engine speed magnetic speed sensor and appropriate wheel shall be provided by the Contractor mounted on the engine and compatible with a Woodward 9900-433 electronic governor. If the Contractor wishes not to use the Government provided 9900-433 governor, then the Contractor shall provide a substitute system in accordance with this spec with the full system price included in this bid.	
2	Engine Start Command	1	28 VDC Command 4 Amp Max ***	Two conductor command from existing LOCOP-maintained until crank terminate is received or LOCOP fail to start delay times out, or until operator releases the start button.	L2
3	Barring Device Limit SW	1	Isolated Contact ***	Two conductor normally closed switch. Switch shall open when barring device is engaged. This contact shall be in series with Item 2.	S12
4	Crank Terminate Switch	1	Isolated Contac ***	Two conductor normally closed contact. This contact shall open when the engine reaches self sustaining speed. This contact shall open the Item 2 current.	S11
5	Engine Actuator/ Normal Stop Command Signal	1	Actuator Signal/Stop Command ***	This two conductor shielded signal from the LOCOP normally carries the actuator signal from the switchboard mounted Woodward 2301A until LOCOP logic commands a normal stop at which time the LOCOP will send a 20-28 VDC stop command on these conductors. This command may be either maintained until LOCOP timer and logic automatically releases this stop signal (normal stops) or maintained until LOCOP operator initiates a local reset (if abnormal or emergency conditions create the stop command). LOCOP emergency stops and air shutoff closed (Item 7) will also command normal stop.	
6	Engine Emergency Stop Command	1	28 VDC Command 8 Amp Max ***	Two conductor command from LOCOP logic energized if LOCOP receives EPCC emergency stop command, overspeed (Item 8), or halon actuated signal. This command will be maintained until Item 9 contact opens when fuel pressure is removed and the engine shuts down. This command shall also initiate engine air intake shutoff and emergency shutdown. The air shutoffs shall require manual re-opening after being closed.	L1

*** = The Contractor shall wire these circuits to the Contractor supplied Interface/Connection Box.

Table I (con't)
SIGNAL INTERFACES

Item	Name	Per Engine Quantity	Signal Type	Notes	Identified As
7	Air Damper Closed Switch(es)	1 Circuit	Isolated Contact(s) ***	One limit switch contact per engine air shutoff, wired in parallel if more than one air shutoff is provided. The circuit when closed will maintain a normal stop command (Item 5).	S16 or S16L, S16R
8	Engine Overspeed	1	Isolated Contact ***	One normally open two conductor circuit which closes when engine overspeed is detected and remains closed until manually reset after overspeed shall be provided. If this circuit is provided Electronically, it shall be independent from ECU systems and shall utilize an independent magnetic speed pickup.	S10
9	Logic Enable	1	Isolated Contact ***	One two conductor circuit, closed when the engine is at and above crank termination speed and operating fuel pressure to the system is established shall be provided. This will be used by LOCOP logic to initiate a 10 sec start delay (to allow time for the engine to establish normal L.O. Pressure) and a short delayed release after normal and emergency stops.	S8
10	Lube Oil Press Switch	1	Isolated Contact ***	One normally closed two conductor lube oil low pressure shutdown switch which opens when engine is operating at idle speed and above shall be provided. If this contact closes after the 10 sec start delay, a normal stop command (Item 5) will be maintained until the engine is shutdown and an operator pushes a trouble reset pushbutton on the LOCOP.	S9
11	Engine Running Switch	1	Isolated Contac ***	One normally closed two conductor circuit that opens when the engine is firing and increasing to idle speed and above shall be provided. This contact will be used in LOCOP logic to prevent timeout of a 15 second fail to start delay relay that is activated when an engine start (EPCC or LOCOP) is initiated.	S17
12	Engine Trouble Reset	1	28 VDC Command 4 Amp Max ***	This normally de-energized signal is on when the operator is pushing a spring return trouble reset pushbutton on the LOCOP. This signal is provided to the Contractor for resetting any electrically latched shutdown logic or circuits so that an operator doesn't have to initiate any resetting operations from the interface/connection box or engine mounted instrumentation panel. Activation of this signal while the engine is running shall not cause an engine shutdown or disturbance.	TRR

*** = The Contractor shall wire these circuits to the Contractor supplied Interface/Connection Box.

Table I (con't)
SIGNAL INTERFACES

Item	Name	Per Engine Quantity	Signal Type	Notes	Identified As
13	Engine Sump Level Low Switch	1	Isolated Contact *** ***	This two conductor normally closed low sump level switch opening when the sump level is greater than low shall be provided. The switch location and type shall be such so as not to cause nuisance alarms due to ships rolling and pitching motion. This switch provides input to a non-delayed alarm circuit in the machinery control system.	S13
14	Lube Oil Supply Pressure to Engine Transmitter	1	4-20 mA = 0-100 PSIG ***	The Contractor shall provide a 4-20 mA pressure transmitter mounted and piped to sense lube oil pressure after the lube oil filters. This transmitter will provide a pressure signal to operate a 0-100 PSIG meter on the LOCOP. The LOCOP will provide the DC power.	MT5
15	Lube oil Filter Diff. Pressure Transmitter	1	4-20 mA = 0-30 PSID ***	The Contractor shall provide a 4-20mA pressure transmitter mounted and piped to sense lube oil filter differential pressure. The signal will operate a LOCOP 0-30 PSID pressure meter and will be powered by LOCOP DC power supply.	MT6
16	Engine Lube Oil Supply Temperature	1	100 ohm Platinum 3 Wire RTD ***	The Contractor shall provide a engine mounted RTD and thermowell to sense engine oil temperature supplied to bearings. This signal will be used to provide an analog temperature to the EPCC.	RTD2
17	Engine Lube Oil Return Temperature (to sump)	1	100 ohm Platinum 3 Wire RTD ***	The Contractor shall provide a engine mounted RTD and thermowell to sense engine oil temperature returning to engine sump. This signal will be used to provide an analog temperature to the EPCC.	RTD3
18	Engine Turbocharger discharge Air Pressure Transmitter	1	4-20 mA= 0-100 in. Hg. * 0-50 in. Hg ** ***	The Contractor shall provide a 4-20 mA pressure transmitter (AMETEK) mounted and piped to sense turbocharger discharge air pressure. The signal will be used to provide an alalog pressure signal (two wire) to the EPCC.	MT8
19	Engine Cylinder Temperature	1 per Cylinder	Type K Thermocouple	The Contractor shall provide one Type K thermocouple minimum per cylinder including connectors or connection head suitable for connecting to armored AWG 16 stranded type TCKX-1 or LSTCKX-1 cable. These thermocouples will connect via Government furnished cable to a Government furnished thermocouple compensation box then to the EPCC for monitoring and alarm.	No. 1 – No. X X<16

* = For Turbos that proved > 50 in. Hg Pressure.
** = For Turbos that do no produce > 50 in. Hg Pressure.
*** = The Contractor shall wire these circuits to the Contractor supplied Interface/Connection Box.

Table I (con't)
SIGNAL INTERFACES

Item	Name	Per Engine Quantity	Signal Type	Notes	Identified As
20	Engine Common Exhaust Temperature	1	Type K Thermocouple	The Contractor shall provide one Type K thermocouple in the exhaust line common to all cylinders including connectors or connection head suitable for connecting to armored AWG 16 stranded type TCKX-1 or LSTCKX-1 cable. This thermocouple will connect via Government furnished cable to a Government furnished thernocouple compensation box then to the EPCC for monitoring	No. 17
21	Serial Data and Remote Monitoring and Control Terminal	1	***	The Contractor shall provide a serial data link, a remote monitoring and control terminal, and software for monitoring and control for display of other important engine parameters. This terminal and data link shall operate up to 300 feet remote from the engine. The remote monitoring and control terminal may be a laptop type computer.	
22	Emergency Stop Switch Activated	1	Isolated Contact ***	The Contractor shall provide a normally open contact with a 6800 ohm resistor in parallel to provide for a remote alarm to inform that the emergency stop switch on the engine mounted instrumentation panel has been activated. After activation this switch contact shall remain closed until the switch is manually reset by an operator.	
23	Ships Power	1	440 VAC 3 Phase 60 Hz 15 Amps Max	Ships power in accordance with MIL-STD-1399 Section 300 Type I will be provided. The Contractor shall use this power to provide for operation of his system, power supplies, and battery charger.	
24	24 to 30 VDC Power to LOCOP	1	24 to 30 VDC 20 Amps	The Contractor shall provide a battery backed up no break power supply system power feed for operation of LOCOP circuits and relays.	
25	Battery Discharging Ships		***	The Contractor shall provide an isolated contact which shall be open when either and both battery charging systems are charging the batteries. The contact shall close when the battery is discharging. The contact shall fail closed when all power sources (including the battery) are off.,	
26	Sips Power	1	440 VAC 3 Phase 60 Hz 15 AMPs Max	Ships power in accordance with MIL-STD-1399 Section 300 Type I will be provided. The Contractor shall use this power to provide power to the Contractor supplied electric preheater controller and preheater.	
27	Secondary ECU in Control	1	Isolated Contact ***	A contact to provide for remote alarm if the secondary ECU assumes control upon loss of the primary ECU shall be provided.	

*** = The Contractor shall wire these circuits to the Contractor supplied Interface/Connection Box.

3.1.2 Definitions

a. APD Automatic Paralleling Device
b. CCS Centralized Control Station
c. DRU Digital Reference Unit – Provides speed raise/lower and reset to 60 Hz inputs to WGC 2301A
d. ECU Electronic Control System
e. EGB-2P A WGC reverse acting actuator for controlling a fuel rack, contains a mechanical overspeed limiting flyball governor. Loss of electrical current results in maximum engine speed and shutdown via the hydro/mechanical electrical device.
f. EPCC Electric Plant Control Console
g. ICAS Integrated Condition Assessment System
h. ICD Interface Control Drawing
i. ICSM Instrument and Control System Monitoring
j. LOCOP Local Control Panel – A panel mounted outside the engine/generator enclosure containing relay logic for basic engine protective logic (loss of L.O. pressure, overspeed, emergency stop, starting delays, MCCS, SAC, prelube pump control, switchboard breaker trip logic and various MCCS alarms) (see Figure 13)
k. MCCS Machinery Centralized Control System
l. MPU Magnetic Speed Pickup
m. NBPS No Break Power Supply
n. SAC Starting Air Compressor
o. SWBD The switchboard designated for the generator (4 generator SWBDs)
p. WGC Woodward Governor Corporation – Fort Collins, Colorado
q. 2301A 9900-433 Woodward Governor Electronic Load Sharing Device – Located in the generator switchboard (one per engine)

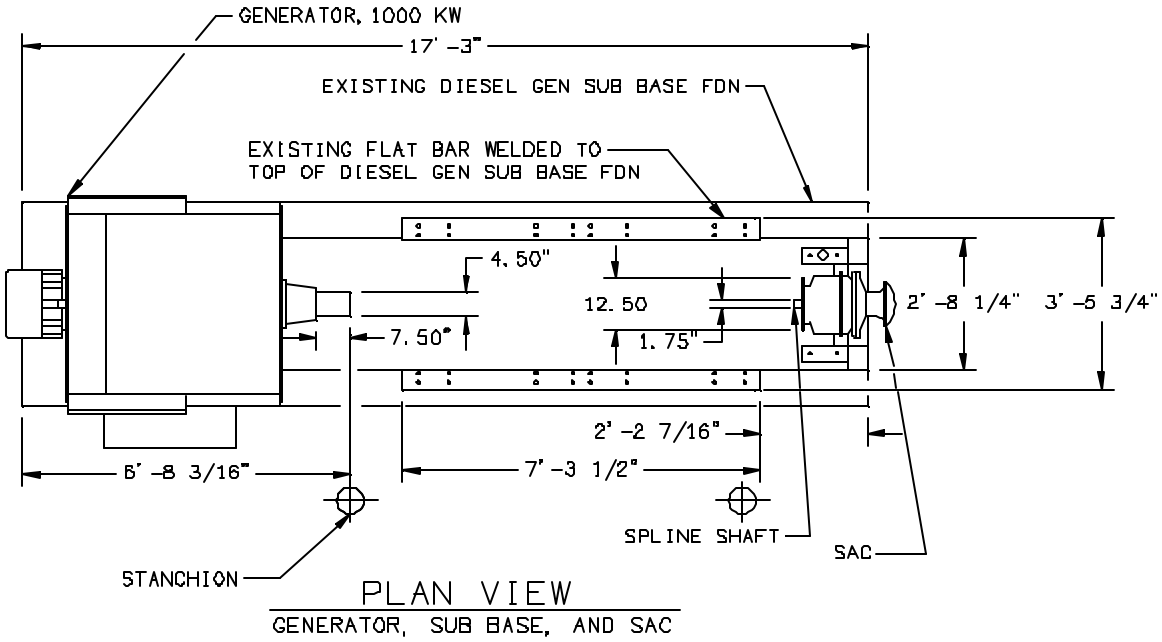

GENERATOR, 1000 KW
17' -3"
EXISTING DIESEL GEN SUB BASE FDN
EXISTING FLAT BAR WELDED TO
TOP OF DIESEL GEN SUB BASE FDN
4.50"
12.50
7.50"
1.75"
2' -8 1/4"
3' -5 3/4"
2' -2 7/16"
6' -8 3/16"
7' -3 1/2"
SPLINE SHAFT
SAC
STANCHION
PLAN VIEW
GENERATOR, SUB BASE, AND SAC

Figure 1

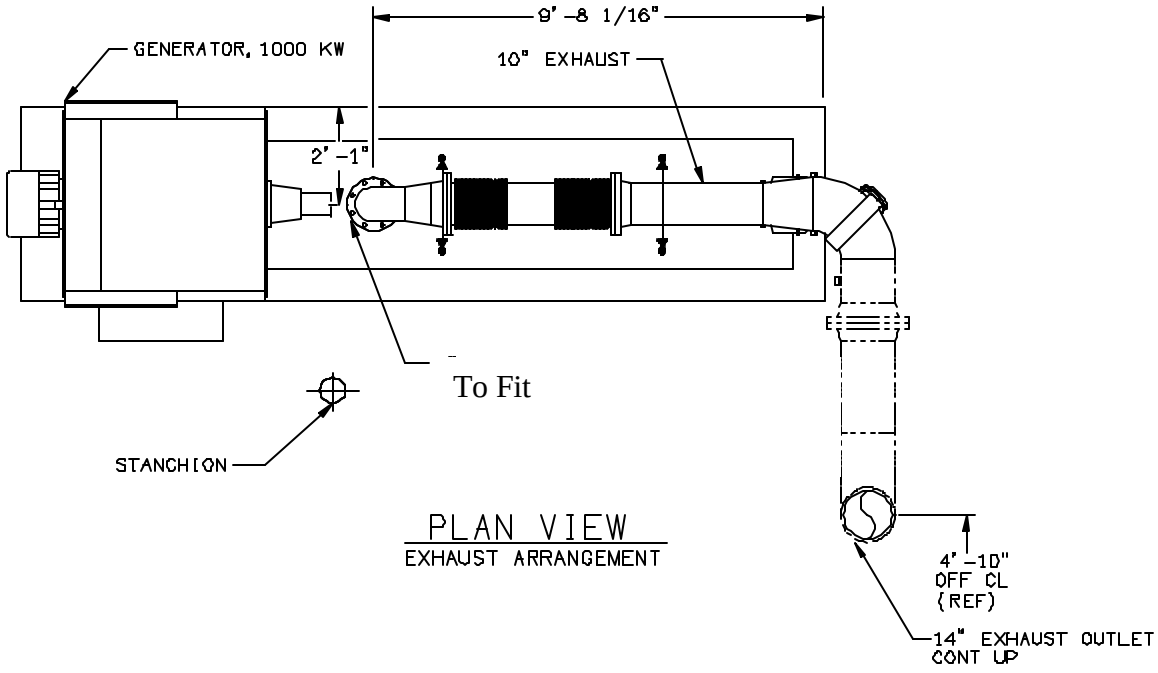

9' -8 1/16"
GENERATOR, 1000 KW
10" EXHAUST
2' -1"
To Fit
STANCHION
PLAN VIEW
EXHAUST ARRANGEMENT
4' -10"
OFF CL
(REF)
14" EXHAUST OUTLET
CONT UP

Figure 2

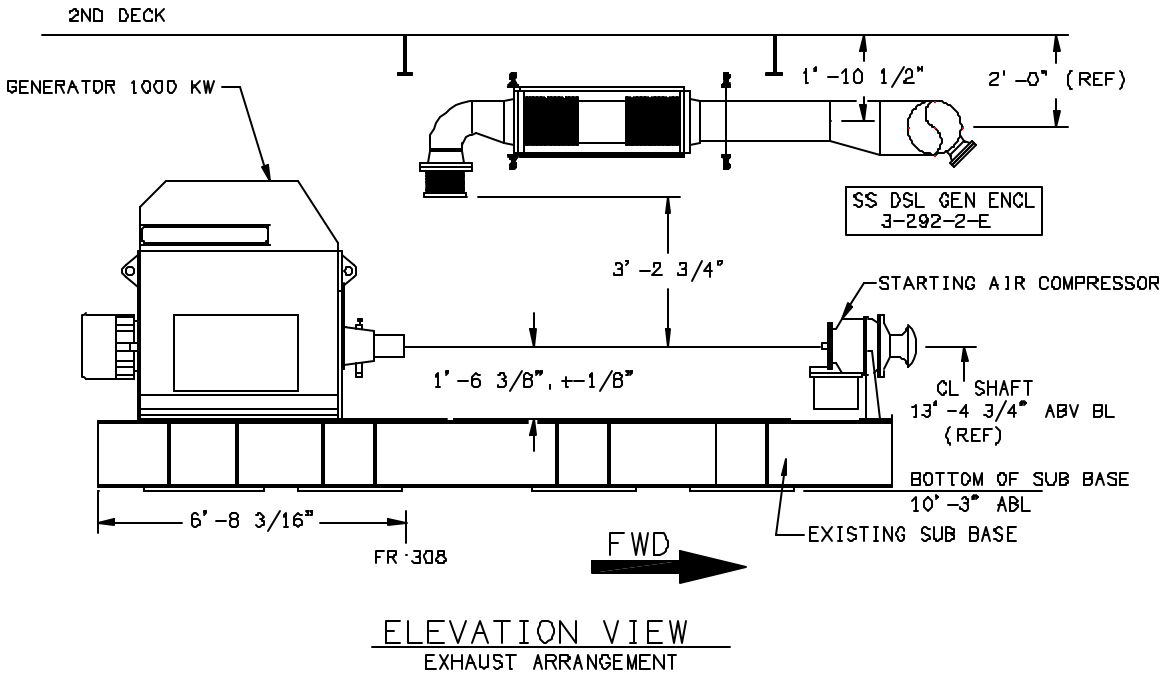

2ND DECK
GENERATOR 1000 KW
1'-10 1/2"
2'-0" (REF)
SS DSL GEN ENCL
3-292-2-E
3'-2 3/4"
STARTING AIR COMPRESSOR
1'-6 3/8", +-1/8"
CL SHAFT
13'-4 3/4" ABV BL
(REF)
BOTTOM OF SUB BASE
10'-3" ABL
6'-8 3/16"
FR 308
FWD
EXISTING SUB BASE
ELEVATION VIEW
EXHAUST ARRANGEMENT

Figure 3

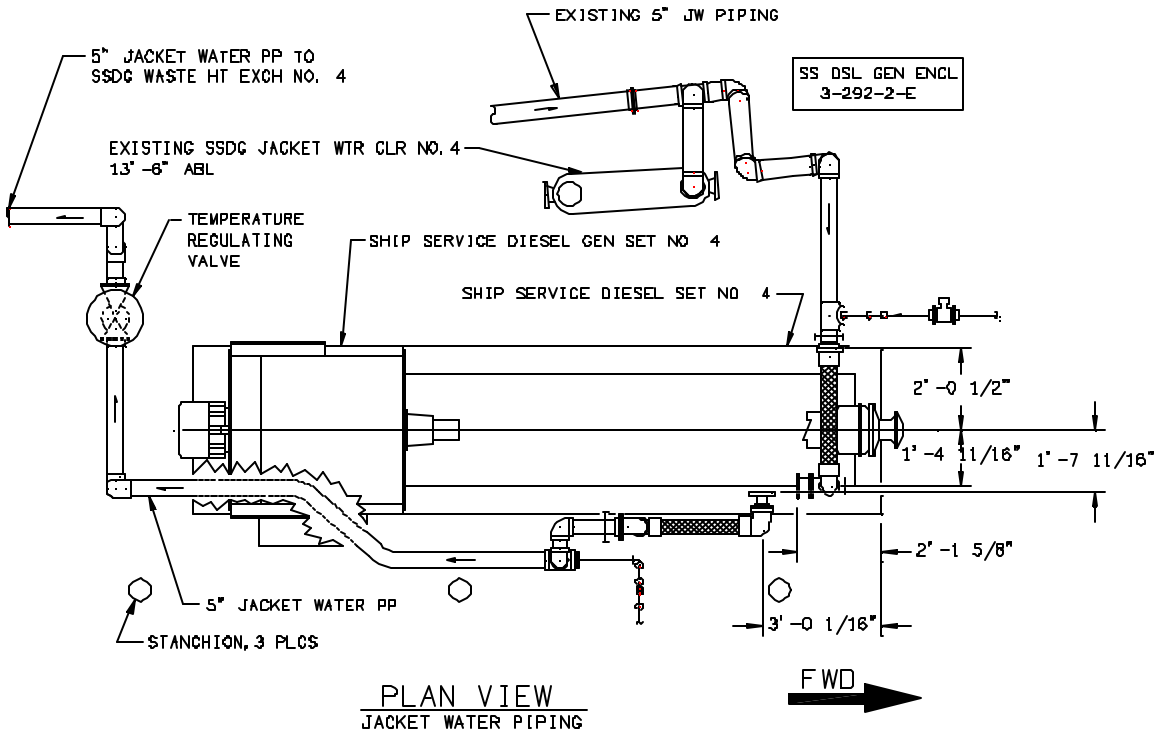
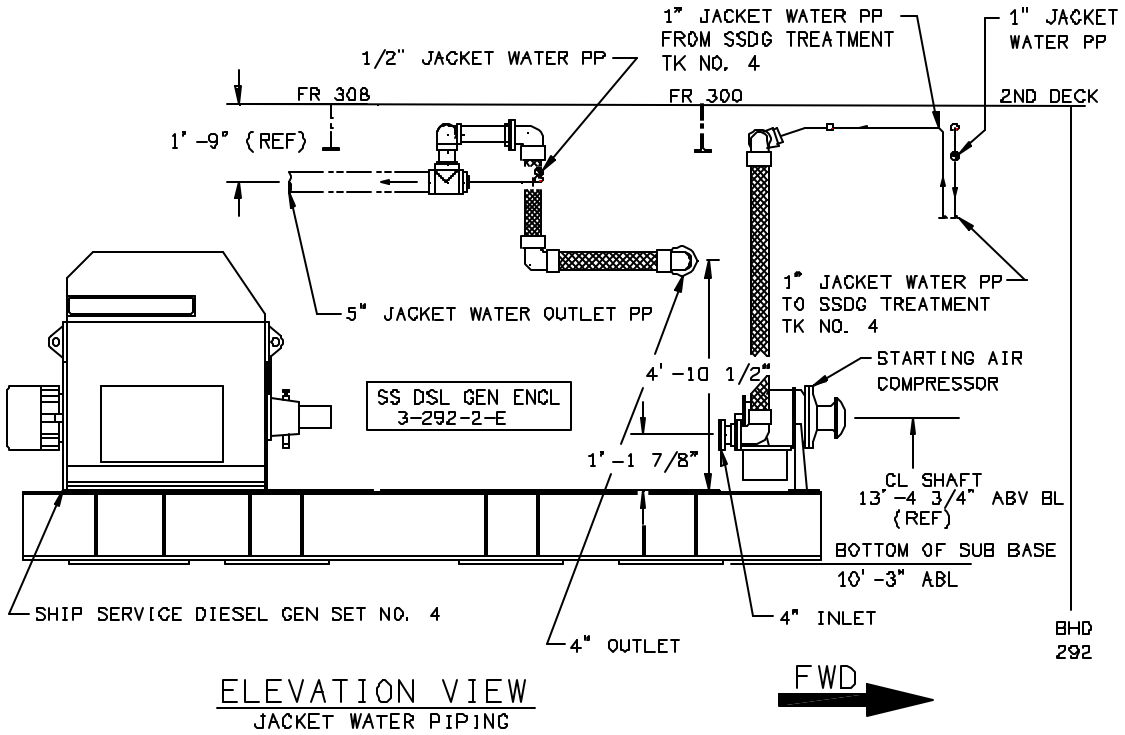

EXISTING 5" JW PIPING
5" JACKET WATER PP TO
SSDG WASTE HT EXCH NO. 4
SS DSL GEN ENCL
3-292-2-E
EXISTING SSDG JACKET WTR CLR NO. 4
13'-6" ABL
TEMPERATURE
REGULATING
VALVE
SHIP SERVICE DIESEL GEN SET NO 4
SHIP SERVICE DIESEL SET NO 4
2'-0 1/2"
1'-4 11/16"
1'-7 11/16"
2'-1 5/8"
3'-0 1/16"
5" JACKET WATER PP
STANCHION, 3 PLCS
PLAN VIEW
JACKET WATER PIPING
FWD

Figure 4



ELEVATION VIEW
JACKET WATER PIPING

Figure 5

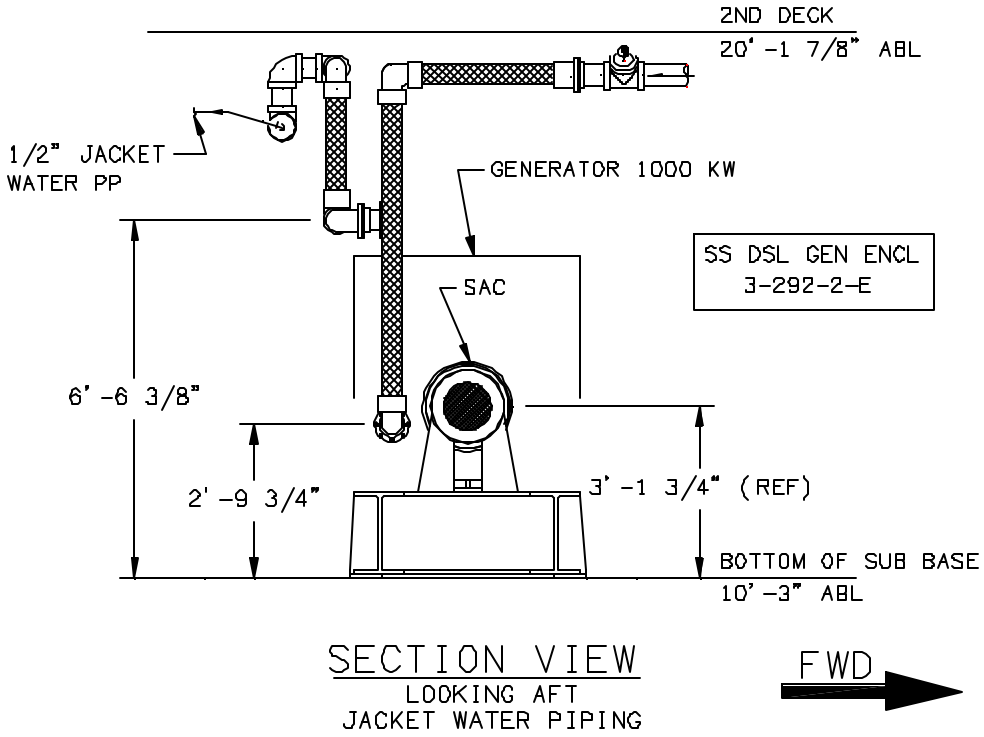

2ND DECK
20'-1 7/8" ABL
1/2" JACKET
WATER PP
GENERATOR 1000 KW
SS DSL GEN ENCL
3-292-2-E
SAC
6'-6 3/8"
2'-9 3/4"
3'-1 3/4" (REF)
BOTTOM OF SUB BASE
10'-3" ABL
SECTION VIEW
LOOKING AFT
JACKET WATER PIPING
FWD

Figure 6

-

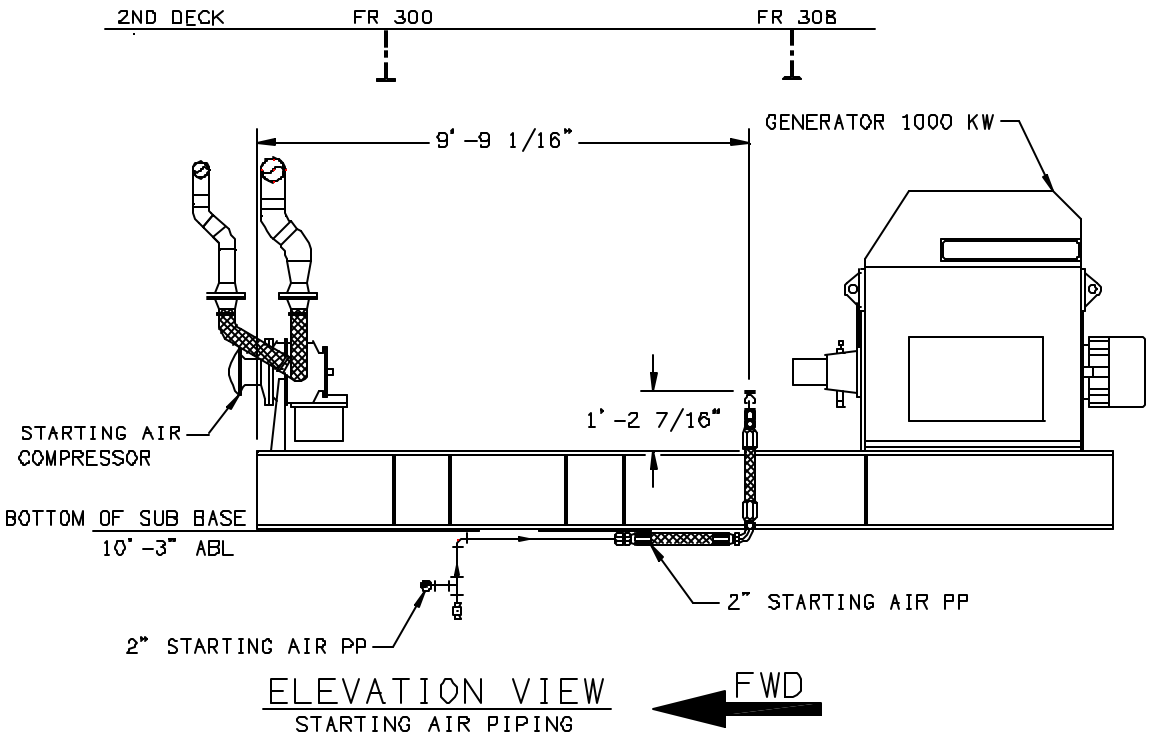

2ND DECK
FR 300
FR 308
9'-9 1/16"
GENERATOR 1000 KW
1'-2 7/16"
STARTING AIR
COMPRESSOR
BOTTOM OF SUB BASE
10'-3" ABL
2" STARTING AIR PP
2" STARTING AIR PP
ELEVATION VIEW
STARTING AIR PIPING
FWD

Figure 7

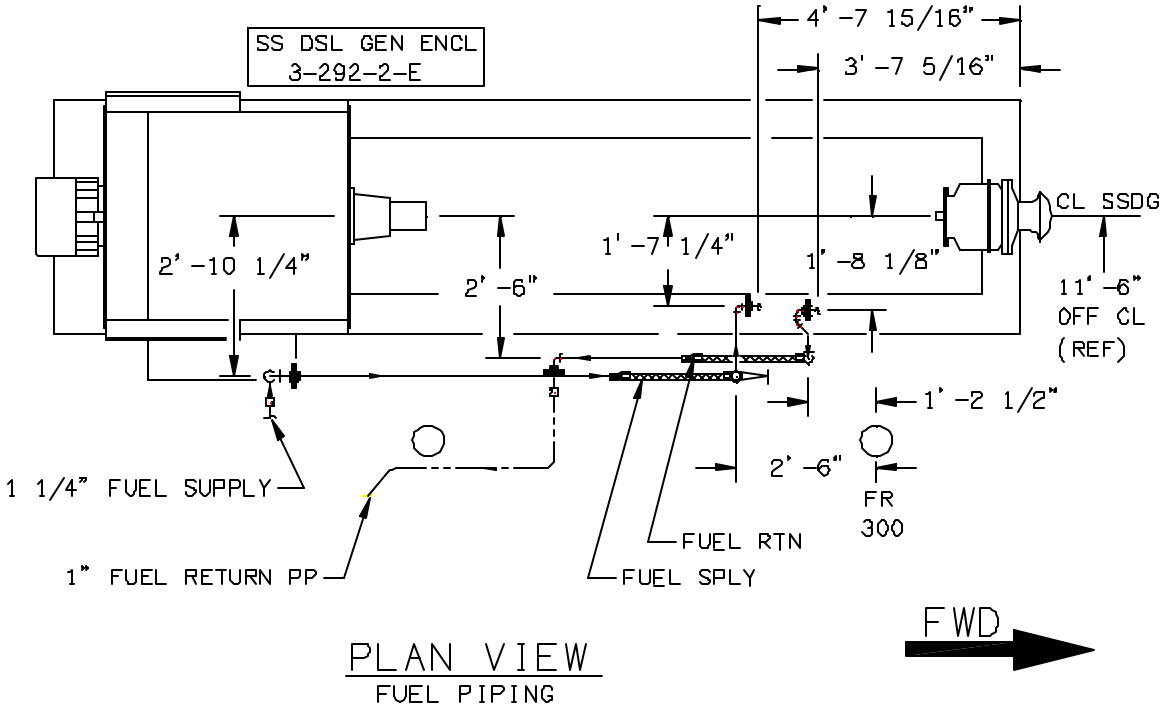

SS DSL GEN ENCL
3-292-2-E
4' -7 15/16"
3' -7 5/16"
CL SSDG
2' -10 1/4"
2' -6"
1' -7 1/4"
1' -8 1/8"
11' -6"
OFF CL
(REF)
1' -2 1/2"
2' -6"
FR
300
1 1/4" FUEL SUPPLY
1" FUEL RETURN PP
FUEL RTN
FUEL SPLY
FWD
PLAN VIEW
FUEL PIPING

Figure 8

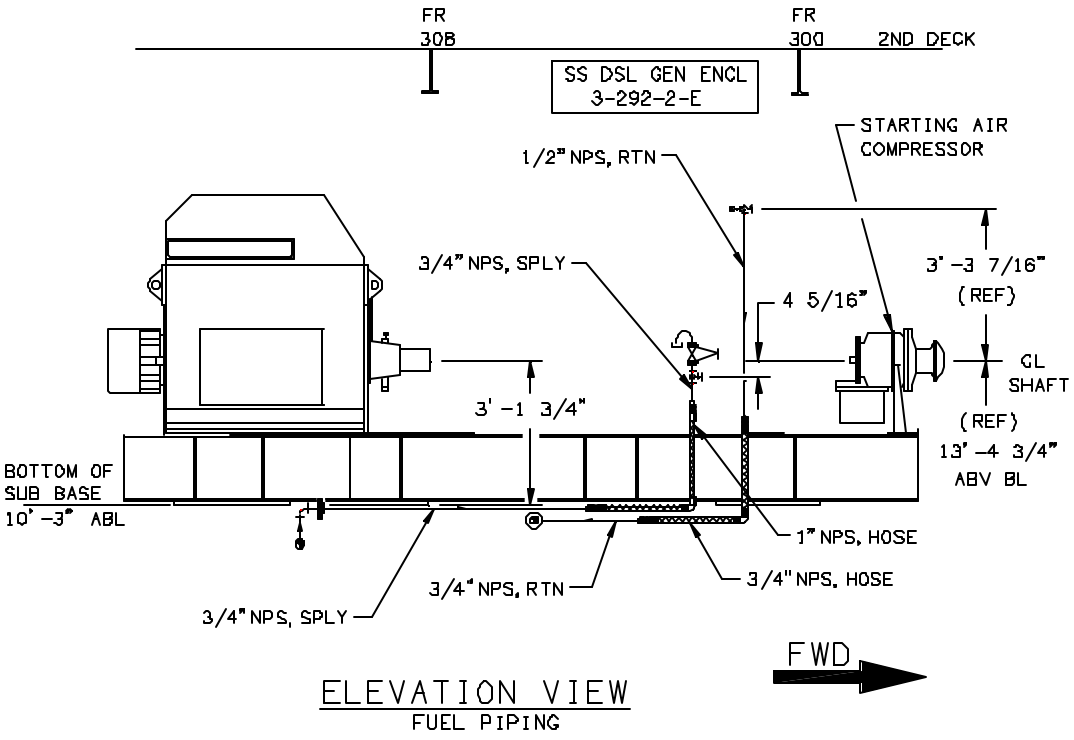

FR
308
FR
300
2ND DECK
SS DSL GEN ENCL
3-292-2-E
STARTING AIR
COMPRESSOR
1/2" NPS, RTN
3/4" NPS, SPLY
3' -3 7/16"
(REF)
4 5/16"
CL
SHAFT
3' -1 3/4"
(REF)
13' -4 3/4"
ABV BL
BOTTOM OF
SUB BASE
10' -3" ABL
1" NPS, HOSE
3/4" NPS, RTN
3/4" NPS, HOSE
3/4" NPS, SPLY
FWD
ELEVATION VIEW
FUEL PIPING

Figure 9

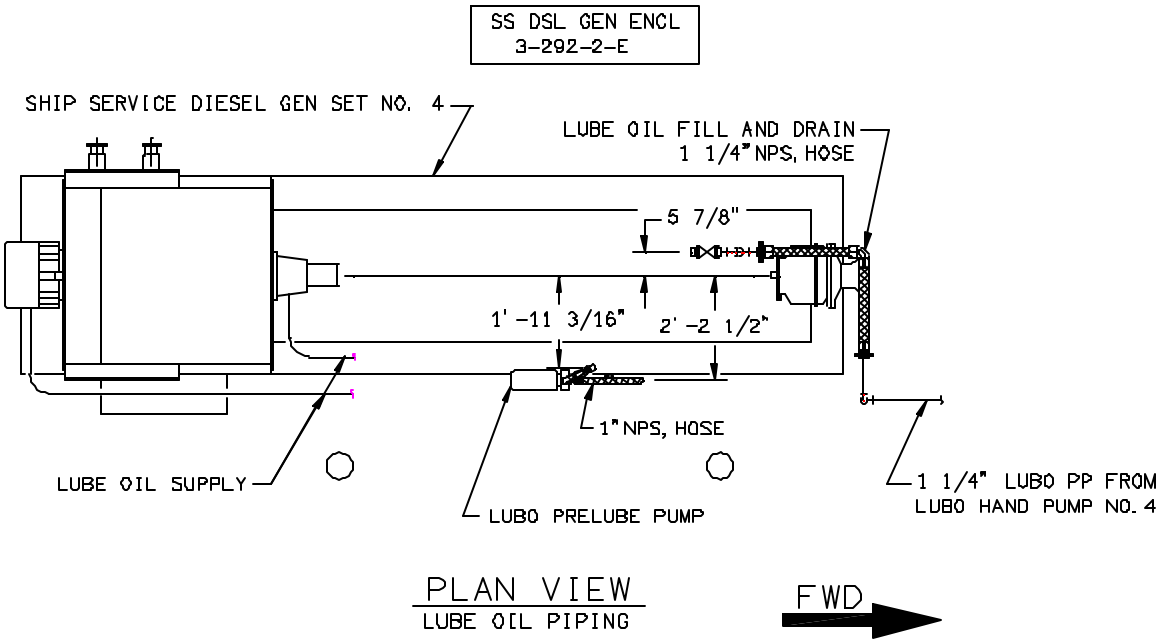
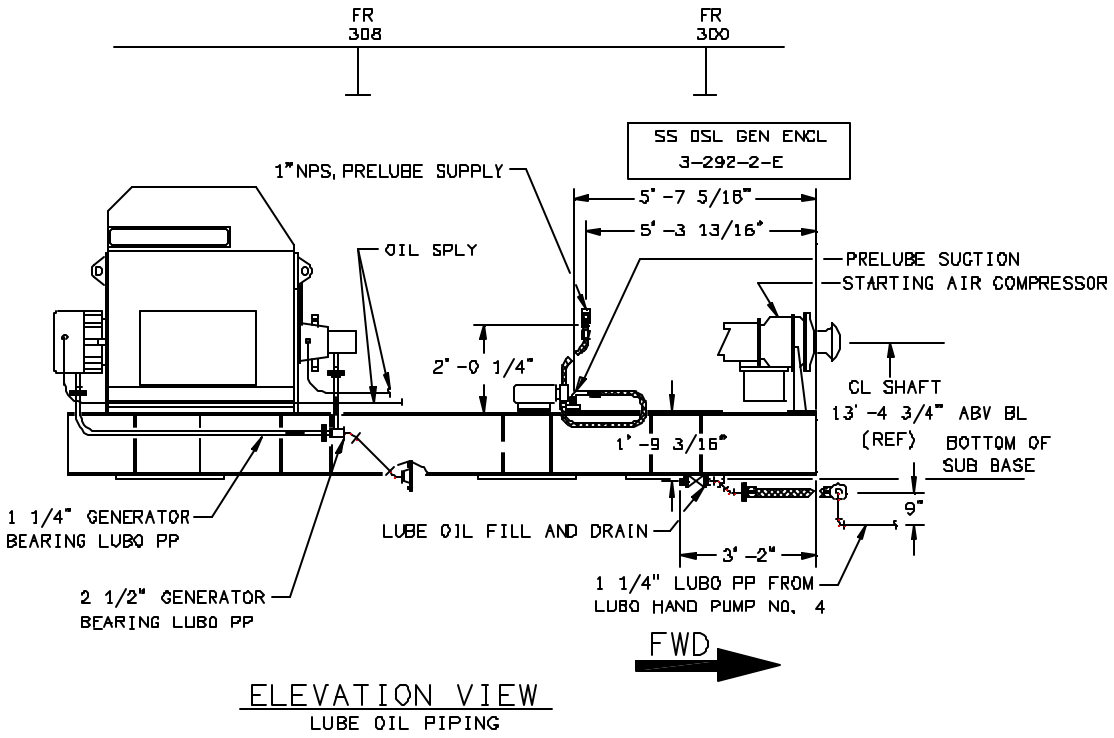
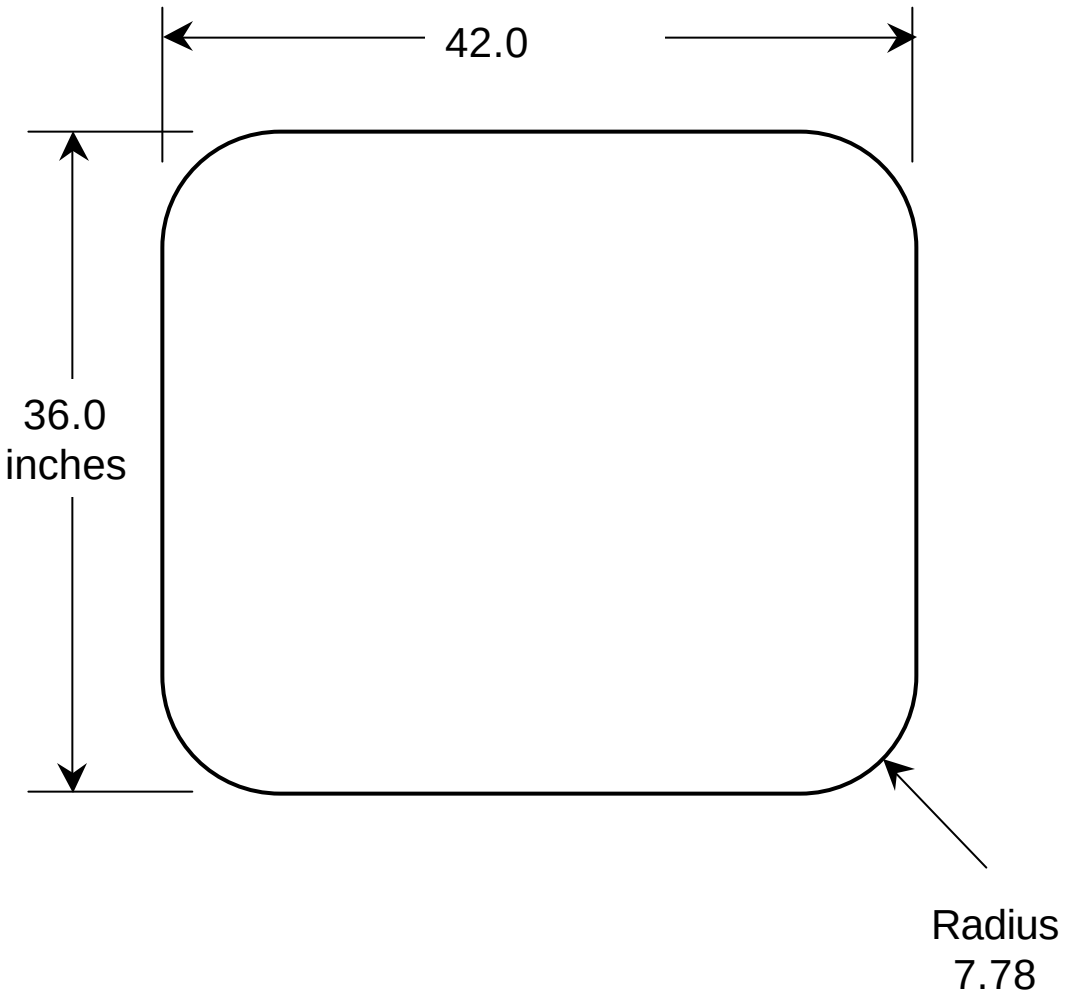

SS DSL GEN ENCL
3-292-2-E
SHIP SERVICE DIESEL GEN SET NO. 4
LUBE OIL FILL AND DRAIN
1 1/4" NPS, HOSE
5 7/8"
1' -11 3/16"
2' -2 1/2"
1" NPS, HOSE
LUBE OIL SUPPLY
LUBO PRELUBE PUMP
1 1/4" LUBO PP FROM
LUBO HAND PUMP NO. 4
PLAN VIEW
LUBE OIL PIPING
FWD

Figure 10



ELEVATION VIEW
LUBE OIL PIPING

Figure 11

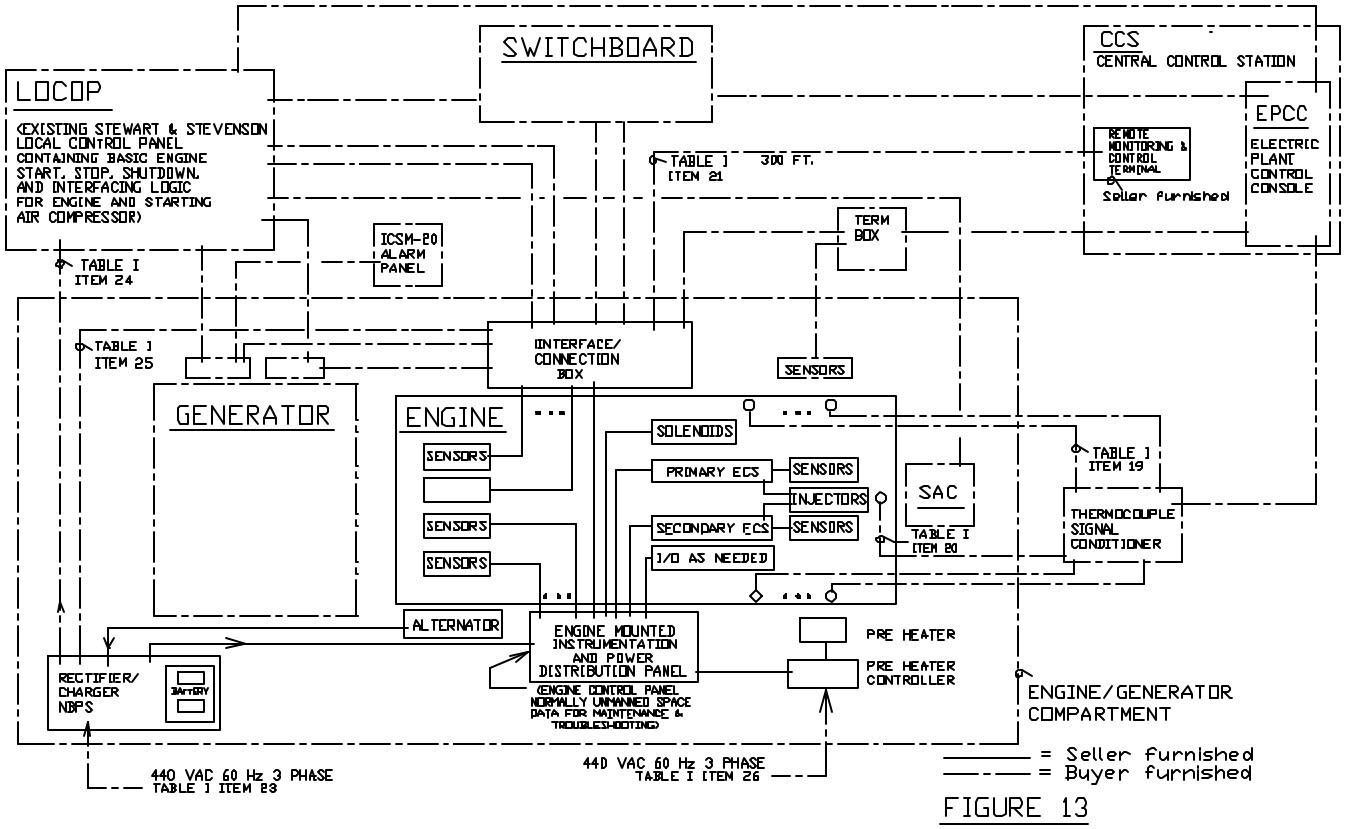


FFG7 Class Access Hatch To Generator Machinery Space

Figure 12

-

THIS PAGE INTENTIONALLY BLANK



Engine/Generator Compartment

Figure 13

3.2 Characteristics

3.2.1 Performance The engine shall meet the performance requirements as defined herein.

3.2.1.1 The diesel engine shall operate satisfactorily at all loads using the following:

a. MIL-PRF--2104 lube oils
b. NALCOOL 3000 jacket water coolant
c. Navy Distillate Fuel MIL-F-16884 (NATO F-76)
d. JP-5 Turbine Aviation Fuel MIL-T-5624 (Must perform emergency starts and operation for a minimum of two hours at 50 percent load.)

3.2.1.2 The engine shall operate satisfactorily under the following shipboard conditions:

a. Inlet air temperature at rating condition (32 degrees F to 100 degrees F)
b. Air supply to engine at rating condition (5250 scfm)
c. Intake pressure loss at rating condition (15 inches H_2O maximum including air filter)
d. Atmospheric pressure at rating condition (29.92 inches Hg)
e. Exhaust gas (combined) temperature at rating condition (1100 degrees F maximum)
f. Exhaust gas back pressure a rating condition (27 inches H_2O maximum)
g. Jacket water heat rejection via existing waste heat system.

3.2.1.3 Black Start The engine shall be capable of performing a "black start". A "black start" is defined as a start where sufficient ship service air (120 psi) is available,but ship's electrical power is not available. In the event the ship's electrical power is unavailable, the engine set shall be capable of starting and supplying rated output power.

3.2.1.4 Fuel System Performance The engine shall meet all performance requirements when operating on Naval Distillate Fuel per MIL-F-16884, (NATO Symbol F-76). The engine shall start and operate satisfactorily using JP-5 Turbine Aviation Fuel MIL-T-5624 for a minimum of two hours at 50 percent load.

.

.

3.2.1.5. List, Pitch, Roll, and Trim The engine accessory components and piping systems shall be capable of operating in accordance with all the requirements of this specification and without loss of fluids, loss of lubricating oil pump suction, and without the connecting rods, crankshaft and gears dipping into the oil under the most unfavorable combination of the following conditions of trim, pitch, list, and roll as specified in Table II.

Table II

ENGINE, ACCESSORY COMPONENTS AND PIPING SYSTEMS

ITEM	CONDITIONS	PARAMETER/INCLINATION
a	Trim	Plus or minus 7 degrees
b	Pitch	Plus or minus 6 degrees
c	Time of complete pitch cycle	9 seconds
d	List	Plus or minus 15 degrees
e	Rolling	Plus or minus 35 degrees
f	Time of complete roll cycle	9 through 16 seconds

3.2.1.6 Generator Loading The engine shall be able to start, continue operating and provide rated voltage at the generator terminal, within 10 seconds after the starting mechanism is set in operation. The engine shall be capable of providing full output power immediately after rated terminal voltage is available.

3.2.2 Physical Characteristics As space and weight are of paramount concern in design and arrangement, the engine shall be lightweight and compact consistent with the design, performance, and maintainability requirements specified herein.

3.2.2.1 Size The physical dimensions of the engine shall be as shown on the Interface Control Drawings (ICD) Figures 1 through 13. The physical dimensions of the engine shall be as compact as possible, consistent with the design, performance, and maintainability requirements specified herein. The engine shall be capable of being disassembled to allow passage through an access trunk as shown on Figure 12 during emergency removal and installations.

3.2.2.2 Weight The engine shall be lightweight and compact consistent with the design, performance, and maintainability requirements specified herein. The maximum dryweight for the engine itself shall not exceed 15,000 pounds.

3.2.3 Environmental Conditions

3.2.3.1 Vibration The engine shall meet the following vibration requirements.

a. Torsional Vibration - The engine shall meet the vibration requirements of Type III in accordance with MIL-STD-167-2. The equipment shall be tested under one cylinder misfire condition.
b. Mechanical Vibration – The blackstart system, voltage regulator and power rectifier shall meet the vibration requirements of Type I in accordance with MIL-STD-167-1 from 4 Hz (or lowest attainable frequency) through 14 Hz at a double amplitude of 30 mils.

3.2.3.2 Shock The diesel engine shall meet the Grade A, Class II, Type A, hull mounted, heavyweight shock test requirements of MIL-S-901D. The engine shall be shock qualified in the configuration replicating a shipboard installation, i.e. while coupled to a generator and installed on a resiliently mounted sub-base. For the purpose of shock testing (and other first article tests as approved by the Government), the engine manufacturer will utilize a government furnished generator and sub-base as a platform for performing the test. The Diesel Generator (DG) shall be tested in a manner representing an operational status, with the necessary support services, including electrical power, starting air, cooling water and exhaust system. The shock test shall consist of a standard four shot test series. The DG is not required to be electrically loaded during the shock test. After the shock test, the DG/engine assembly shall be subject to detailed operational/functional test inspections in accordance with standard factory acceptance test procedures. At the completion of the operational tests, the engine shall be removed from the test platform and subject to a detailed post shock disassembly and visual/dimensional inspection of components. Detailed test procedures and a test report shall be prepared.

.3.2.3.3 For engines that are identical or similar to an engine that has been previously shock tested and approved by the Navy and have met the above test requirements, the Contractor may submit a request for shock approval extension at the time of proposal submission. Requests shall be in accordance with MIL-S-901D.

3.3 Design and Construction

3.3.1 Materials, Parts, and Processes

3.3.1.1 Materials The materials used to construct the engine and its accessories shall be the same material used in standard commercial marine engines except as modified to meet the requirements of MIL-S-901D, Grade A, and as modified herein. Material with less than 10 percent elongation shall not be used for structural members excepts as approved by the Government.

3.3.1.1.1 Hazardous Materials The material shall have no adverse effect on the health of personnel when used for its intended purpose. Materials and parts containing radioactive material, mercury, cadmium, asbestos, carbon, boron fibers, or other materials giving off toxic fumes under operating or casualty conditions shall not be used.

3.3.1.1.2 Magnesium Alloys shall not be used.

3.3.1.1.3 Asbestos and materials containing asbestos shall not be used.

3.3.1.1.4 Mercury, mercury compounds, or instruments containing mercury or mercury compounds shall not be used.

3.3.1.1.5 Silver shall not be used in areas where it comes in contact with lube oil.

3.3.1.1.6 Sodium Chromate corrosion inhibitors shall not be used.

3.3.1.1.7 Dissimilar Metal Contact between dissimilar metals shall be avoided in order to minimize corrosion. An interposing material which will minimize or eliminate this galvanic effect shall be used.

3.3.1.1.8 Aluminum Parts , other than pistons, blowers and fuel pumps shall be protected from corrosion by one of the following methods:

a. The alloys in contact with the jacket water shall be compatible with the coolant inhibitor
b. Copper bearing alloys and aluminum shall not be combined in the jacket water cooling system.

3.3.1.2 Processes

3.3.1.2.2 Fabrication Welding and Inspection requirements for the engine shall be in accordance with the manufactures existing procedures.

3.3.1.2.3 Coatings No cadmium plating shall be used on engine parts, including fasteners.

3.3.1.2.4 Painting Flexible hoses, rubber bushings, hose fittings, valve stems, grease fittings, gauges, and internal engine lubricating-oil and fuel passages, shall remain unpainted.

3.3.1.3 Parts

3.3.1.3.1 Inserts Where through bolting of normally serviced aluminum parts is not possible, corrosion resistant or corrosion protected steel inserts shall be cast or threaded into the aluminum or aluminum alloy. The inserts shall include a method of locking the insert in place to prevent backing out when in use. Length of engagement shall be such as to develop the full strength of the bolt. No alloys of copper (brass bronze, copper-nickel, or nickel-copper) shall be used in threaded contact with aluminum alloys. Washers of the same material and coating as the bolts shall be fitted below all nuts and bolts heads which adjoin aluminum or aluminum alloys.

3.3.1.3.2 Threaded Fasteners and Plugs Drain plugs shall be readily removable without the use of special tools. Fasteners shall be identified on drawings or in tech manuals by a part identification number (PIN), size, pitch, length and material for reference by the user. Unless otherwise specified, no metric fasteners are permitted for connections to ship piping systems.

3.3.2 Nameplates and Product Marking The engine shall be marked for identification using suitable nameplates. Complete accessory components such as Contractor furnished pumps, coolers, filters, speed control devices, electrical and starting equipment shall have identification plates showing the manufacturer's name, model or part number, and capacities or ratings where applicable. Pump castings shall have an arrow cast on the housing or a plate secured tot he casing indicating the direction of rotation.

3.3.3 Safety

3.3.3.1 Guards and Shields shall be furnished for the engine to eliminate or control safety hazards to personnel and equipment.

3.3.3.2 Guards for the protection of personnel shall be provided for exposed moving parts and/or electrical equipment.

3.3.3.3 Shields The engine shall be designed to preclude the possibility of a fire due to a fuel oil or lubrication oil leak by one, or a combination of the following methods.

a. Exposed hot external engine surfaces shall be shielded or insulated so that no such surfaces exceed a temperature of 428 degrees F under any operating conditions. Asbestos insulating products or materials shall not be used.
b. Fittings on fuel and lubrication oil lines, including gage lines, shall be located or shielded so that lube oil or fuel oil leakage cannot drip or spray on exposed external engine surfaces, whose temperatures are expected to exceed 428 degrees F under any operating condition.

3.3.4 Identification and Marking The engine shall be provided with an identification plate secured to the engine in a visible and convenient location. The identification plate shall be of metal and shall show the following:

a. Engine type
b. Serial number
c. National Stock Number (NSN) (if available)
d. Contract number
e. Model number & Manufacturer Name
f. rpm
g. Bhp (at rated rpm)
h. Rotation direction
i. Bore
j. Stroke
k. Dry weight
l. Firing order
m. Month/Year manufactured

3.3.4.1 Rotation Indicator A plate or similar device with an arrow showing direction of rotation shall be secured to the engine at the drive end of the engine. The engine crankshaft rotation shall be designated counterclockwise as viewed from the main drive end (flywheel end). The right and left side of the engine shall be designated as viewed from the main drive end (flywheel end).

3.3.5 Workmanship shall be uniform in quality, and the surfaces shall contain no foreign matter, corrosion, or detrimental defects such as perforations, sharp edges or corners, seams, cracks, laps, dents, raised metal, nicks, scratches, burrs, or other irregularities that might adversely affect performance, reliability, maintainability or safety. Fluid leaks are not acceptable; Where gasket sealants are required they shall be of the non-hardening type, and shall be sparingly applied.

3.4 Documents Drawings and other documentation for the engine shall be furnished as follows.

3.4.1 Drawings Specific drawings to be provided for approval include drawings for the engine, and attached and unattached accessories; drawings of production or existing parts, components, or equipment applicable to a contract or order, and shall consist of the manufacturer's commercial shop drawings; and installation drawings for the engine. All drawings shall be dimensioned using SAE (English) units unless otherwise approved by the Government.

3.4.1.1 Speed Control System

a. An Electronic Control System Assembly Drawing shall consist of plan, elevation, and section views, as required, to show the size, weight, and mounting details of the assembly of the electronic control panel. The drawing shall permit the Government to verify satisfactory operator interface. Identification and orientation of subassembly design details shown on lower tier subassembly drawings need not be repeated on the overall assembly drawing.
b. Speed Control System Wiring Assembly Drawing identifies all input and output (e.g., pin and jack) connections down to the component level, for all wiring within the speed control system. The wiring assembly drawing need not group parts with respect to their actual physical location. Wiring shall include:

    (1) Wiring to Primary and Secondary ECU.
    (2) Wiring to printed wiring boards.
    (3) Wiring to lights and indicators.
    (4) Wiring to power supplies.
    (5) Wiring to Shipbuilder interfaces.

(6) Wiring to ground(s).
(7) Wiring to terminal boards internal and external to the speed control system.
(8) Wiring to transformers (including linear variable differential transformers (LVDTs).
(9) Wiring to solenoids and servomechanisms.
(10) Wiring to switches.
(11) Wiring to speed pickups or a PMA.
(12) Wiring to any other components in the speed control system. (e.g., resistors).

c. Speed Control System Schematic Diagram for troubleshooting which depicts the electrical connections and functions of the speed control system circuitry.

3.4.1.2 Installation Drawings Installation drawings, or other Contractor provided documentation, for the diesel engine set shall be furnished and will contain, as a minimum, the following:

a. Dimensional outline drawings (four view drawings and 3D solid model of the engine, coupling assemblies and each detached accessory. These drawings shall identify and show the location of Shipbuilder connections, both mechanical and electrical.
b. Foundation bolting details.
c. Piping system diagrams, showing pipe sizes, types of connections, relative locations of coolers, valves, strainers and filters, the instruments and instrument connections. They shall also show normal pressure and temperature ranges of oil, air and water systems.
d. Data tables as necessary to clearly describe all equipment including capacities of pumps and blowers or turbochargers at rated speed, rated BHP, RPM, type numbers, ratings (volts, amperes, Pressures and low rates, kW, torque and so forth), name(s) of manufacturer(s).
e. Table of weights showing wet and dry weights of all major units weighing 100 pounds or more.
f. Centers of gravity of engine, major unit weighing 500 pounds in at least 2 planes.

g. Clearance required to remove engine parts.
h. All openings of examination of clearance measurements, and planned maintenance.
i. Maximum amount of heat in BTU per hour dissipated by the engine set into the space.
j. Location, size and capacity of lifting means.
k. Complete wiring diagrams of the diesel controls shall be provided to facilitate Shipbuilder verification of interfaces to the Diesel Generator Local Control Panel (LOCOP), and Electric Plant Control Console.
l. Any additional information the Contractor believes is required for the proper installation, operation and maintenance of the equipment.
m. Shock qualification note in accordance with MIL-S-901.

3.4.2 System Schematic The Contractor shall prepare a control system schematic showing the engine control functions, relations, and connections to the FFG 7 control system.

3.4.3 Weight Control The following information shall be provided to monitor weight control

a. Wet and dry weights of all components and piping.
b. The wet and dry center of gravity (c.g.) of the total engine assembly and each major component supplied shall be shown on the assembly drawing.
c. The method of determination shall be indicated on the drawing (e.g., calculation, physical measurement).

3.4.4 Weight of Fluids Quantities of fluids weighting more than ten pounds shall be considered in the calculation of the wet c.g.

3.5 Human Performance and Human Engineering

3.5.1 Maintenance All parts which require inspection, viewing, preventive maintenance, or replacement in service, shall be accessible, with the minimum practicable need for disconnection or removal of another part or assembly. Access panels, covers, peep holes, etc. may be used.

3.5.2 Accessibility The engine attached accessories such as pumps, blowers, turbochargers, coolers, filters, strainers shall be positioned to permit maximum accessibility to the accessories and the engine. Engines shall be provided with adequate openings with removable covers in the frame and crankcase above the mounting flange for servicing and examining the engine. Removal of the generator and SAC interface couplings shall be accomplished without having to move the engine, generator or SAC from their respective foundations. The Contractor shall demonstrate that the engine (including all supplied components) can be transported through the access trunks shown on Figure 12. Disassembly of the engine is permitted to the extent that allows passage through the access trunk openings.

3.6 Major Component Characteristics

3.6.1 Major Component List

a. Engine
b. Engine mounted instrumentation/power distribution panel
c. Engine mounted interface/connection box
d. Remote monitoring and control terminal
e. Fuel priming pump
f. Duplex fuel and oil filters
g Air inlet overspeed shutoff with single pull cable, limit switches and solenoid operator
h. Air pressure regulator (backup to existing ship's regulator)
i. Barring device with starting interlock
j. Crankcase fumes disposal system
k. Coupling assembly (engine to generator shaft) with guard
l. Engine support assembly (with oil pan) and guard
m. Coupling Assembly (engine to SAC) with guard
n. Transducers, switches and sensors in accordance with Table I
o. Jacket water pump
p. Lubricating oil pressure pump
q. Fuel supply pump
r. Fuel priming pump
s. Lubrication oil cooler
t. Lubricating Oil filter(s)/strainer(s)
u. Temperature regulator or thermostat
v. Engine speed control system components
w. Engine overspeed shutdown device and overspeed detected switch
x. Air starting system

y Engine mounted controls
z. Lubricating oil low-pressure shutdown switch
aa. Instruments
bb. Thermocouples and connection points (engine cylinder temperature measuring device)
cc. Instrumentation root valves
dd Instrumentation gage valves/test valves
ee. Guards and shields
ff. Battery and no break power supply system
gg. Remote monitoring and control terminal
hh. ICAS Interface Port
ii. Aftercooler Heat Exchanger (if required)
jj. Engine mounted alternator

3.6.2 Speed Control System The Speed Control System shall have the function of sensing DG set speed, comparing that speed to the desired speed, and sending an input to the fuel system to obtain and maintain that speed. The Speed Control System shall be capable of adjusting the setting of the desired speed utilizing the Government supplied switchboard connected system.

3.6.2.1 Electronic Speed Control The engine shall operate, start, stop and share load in a safe and stable manner utilizing Government supplied switchboard components and with Contractor supplied electronic speed control components while operating in any mode and at any power level between 0 percent and 110 percent.

3.6.2.2 Electronic Control Unit Primary and standby electronic engine control units(ECU) shall be provided. Mechanical and/or Electomechanical actuators and linkages shall not be utilized. These units shall receive input from engine mounted sensors and speed control devices located in the switchboard and shall provide efficient control of fuel injection by control of individual cylinder fuel injection as well as backup engine protective functions. The primary electronic fuel control system shall be the controlling element for fuel injection when both primary and standby electronic fuel control systems are functioning properly. The standby electronic fuel control system shall assume automatic control of fuel injection if the primary fuel control module fails while the engine is running. The generators shall continue to share load while operating in parallel regardless of failure of either primary or standby electronic fuel control system. The primary and standby ECUs shall receive power from the no break power supply system via the engine mounted instrumentation and power distribution panel. The secondary ECU shall also provide for two status indicators (Secondary ECU active and Secondary ECU ready) located on the engine mounted instrumentation panel. The primary and secondary ECUs shall be capable of producing and sharing data among each other, the engine mounted instrumentation panel, and the remote monitoring and control terminal (primary only) (Table I Item 21). Each ECU shall be fed from an independent engine speed sensing device.

3.6.2.3 Speed Control The switchboards for each generator system will contain some components of a load sharing and governing system. This is a configuration after "MACHALT 431" has been incorporated into FFG switchboards by government personnel. These components include the following:

a. Automatic Paralleling Device - Woodward Model 9900-200
b. Power Selector - Woodward Model 9900-471 which receives two 90-130 VAC inputs and provides a 90-135 VDC output (the output of this device provides power to Items c and h below)
c. Digital Reference Unit – Woodward Model 9900-517. (This unit receives power from Item 2 above and inputs from speed raise, lower, and reset to 60 Hz inputs). The output of this device is a speed trim signal which is applied to a 2301A electronic governor, Item h below).
d. Three Current Transformers (CT) - one per phase of generator current. (These provide input to a 2301A electronic governor Item h below) (Each of these 2000 Amp to 5 Amp current transformer has an externally connected .5 OHM shunt resistors in parallel).
e. Three PT Signals from 4:1 Stepdown Transformers – (Three transformers 450 VAC to112.5 VAC output). (These provide input to a 2301A electronic governor Item h below.
f. Loadshare Enable Circuits - consisting of a series circuit of isochronous mode selected and generator breaker closed status. (This circuit opens when droop mode is selected.) This circuit provides input to a 2301A electronic governor, Item h below)
g. An Idle/Rated Speed Selection Circuit (open for idle, closed for rated speed)
h. Woodward Electronic Governor Type 2301A Model 9900-433 - This device receives inputs from Item a, b c, d, e, f, and g above and provides a load share lines signal used in a circuit connected through bus breaker closed status contacts to other 2301A governors located in other generator switchboards. This 2301A electronic governor provides an output compatible with reverse acting Woodward EGB-2P actuators. This 2301A governor also requires a magnetic speed pickup signal, sensing engine speed, from the engine (see Table I Item 1).

3.6.2.4 The Contractor may use the above switchboard mounted components or may propose other devices as replacements. The Contractor shall include all costs of any other switchboard components which shall be required to provide a compatible and complete speed control system in accordance with this specification in his bid.

3.6.2.5. Enclosures Speed control system shall be engine mounted in enclosure(s) provided by the Contractor. The enclosure(s) shall be spraytight protected, as defined by MIL-STD-108. Electrical interface connections shall be via connectors, to the maximum extent possible.

3.6.2.6 Insulation Resistance the insulation resistance, when corrected to 25 degrees C, shall not be less than 10 megohms. Corrections shall be made on the basis of insulation resistance doubling for each 15 degrees c decrease in temperature.

3.6.2.7 Speed Sensors and Circuitry The speed sensing circuit shall not be affected by disturbance in the voltage of the generator. A guard or shield shall be provided to protect the connections to the speed pickups from damage.

.

3.6.2.8 Mode of Operation The generator and speed control system shall be capable of operating in the following modes:

a. Individually in isochronous mode.
b. Individually in droop mode.
c. In parallel with other shipboard generators in load sharing mode.
d. In parallel with other shipboard generators all in droop mode.
e. In parallel with shore power in droop mode.

3.6.2.9 No Break Power Supply (NBPS) System The Contractor shall provide a NBPS consisting of the following (minimum) components: mimic panel with switches and test points, rectification circuits, regulation circuits, protection circuits, provisions for two input sources, provisions for two DC output feeds, battery discharging alarm circuit, batteries, and battery compartment.

3.6.2.9.1 Input and Ouputs The NBPS shall receive input power from two sources: Ships 440 VAC 3 Phase 60 Hz power in accordance with MIL-STD-1399 Section 300 Type I (Table I Item 23) and a Contractor supplied engine mounted alternator. The NBPS shall provide two DC outputs: Table I Item 24 (24 to 30 VDC 20 Amps to LOCOP) and DC power to Contractor supplied system. A contact closure (Table I Item 25) shall also be provided for remote alarm when the battery is discharging or not connected.

3.6.2.9.2 Batteries and Battery Compartment The batteries shall be maintenance free types contained in a separate compartment of the NBPS enclosure. This compartment shall be isolated from other portions of the NBPS and shall contain only the batteries, battery connecting cables, provisions for battery retaining devices, battery access, and battery compartment ventilation. Batteries shall be adequate to provide a minimum of 30 minutes operation with the LOCOP load at 20 Amps with the engine operating at full load and batteries at 40 degrees F. Recharging of the battery system shall be accomplished within 2 hours of resuming normal operation.

3.6.2.9.3 NBPS Mimic Panel A mimic panel shall be provided on the front of the NBPS enclosure. This mimic panel shall contain representations of various components of the NBPS including batteries, both input sources, both DC outputs. The mimic shall also contain switches and current limited voltage monitoring test points. The following switches shall be provided on the mimic: A switch to disconnect the battery, a switch to turn off input source (Table I Item 23), a switch to turn off the alternator source. The test points shall be placed on the mimic so that their relationship to the depicted components is obvious. They shall be provided to measure the voltage of each battery individually and serially, the final output voltage of each DC output, and each charger output voltage. Loss of source voltage and/or turning off the input source switch shall cause the voltage at the associated charger output test points to drop to near zero volts. Tags or engravings at the test points shall indicate the normal voltage range and polarities. All front panel switch contacts shall be rated adequately to allow make and break operations under full load and during operation and testing cycles. With either or both inputs powered the DC system output voltage shall be maintained within the 19 VDC to 30 VDC limits regardless of the state of the battery disconnect switch. Input switches shall be used to test that the battery is capable of providing a minimum of 30 minutes operation with all DC outputs on at full load and with the engine running when neither input source is on. During this period neither DC output voltage shall drop below 19 VDC. DC output to the Contractor supplied system shall not cause variations of engine speed during NBPS testing in accordance with Appendix A.

3.6.2.9.4 NBPS Design The NBPS and enclosure shall be natural convection air cooled, drip proof to 15 degrees per MIL-STD-108D, designed and tested to Grade A shock in accordance with MIL-S-901D. The NBPS shall be designed to be mounted in the engine/generator space with ambient temperatures of 32 degrees F to 120 degrees F. The NBPS shall be in accordance with the EMI requirements of paragraph 3.7. The NBPS shall maintain continuous DC output so as not to disturb the engine or LOCOP operation upon loss and restoration of either and both charging sources. Each input charger shall be sufficient to provide for engine and LOCOP operation and battery charging with all DC outputs at maximum load. The system output voltage shall not exceed 30 VDC regardless of system DC output loads. The battery shall be protected against overcharge and battery damaging over discharge.

3.6.3 Engine

3.6.3.1 Service Experience The engine shall be a current production engine model with a demonstrated background of service experience. In addition to meeting all other requirements of this specification, 6 production engines, at the time of the bid, shall have accumulated a total of 50,000 documented engine-hours of Naval or commercial marine service at power ratings greater than or equal to the 100 percent full-load brake horsepower (bhp) proposed for test. At least two of these engines shall have 10,000 operating hours each without overhaul. At least 20 percent of the engine hours shall have been accumulated at a power greater than or equal to 80 percent of the rated load. The Contractor shall provide service and experience documentation which shall include:

a. Name, address, phone number, and point of contact of company operating engine
b. Location of engine
c. Application of engine
d. Year the engine entered application.
e. Nameplate date

(1) Model number
(2) Serial number
(3) Engine rating
(4) hours of operation
(5) hours per year
(6) operation profile

3.6.3.2 Standard Operating Conditions The following operating conditions shall be used for the design of the engine and accessories:

Table III
CHARACTERISTICS

ITEM	CONDITION	TEMPERATURE
a	Ambient air temperature	32 degrees F through 100 degrees F
b	Barometric air pressure (dry	29.92 inches Hg
c	Intake air restriction	15 inches H_2O
d	Exhaust backpressure	27 inches H_2O
e	Exhaust gas temperature	1100 degrees F maximum

3.6.3.3 Air Starting System The air starting system shall consist of the starting equipment including motor or distributor and applicable valves, strainer, lubricator, lines, connections, and fittings. It shall be capable of actuation by electrical and mechanical means. The diesel engine shall be capable of starting with a minimum air pressure of 100 psig available from the ship's air system. An air starting interlock shall be provided to prevent the engine starting mechanism from being actuated when the engine is in operation.

3.6.3.4 Engine Barring Device The engine set shall be supplied with a manual barring device. The barring device shall be interlocked both mechanically and electrically with the engine starting system such that when the barring device is engaged, the engine cannot be rolled with starting air. The barring device shall also be automatically interlocked so that it cannot be engaged while the engine is running. All interlock(s) shall be designed to function under all conditions, including local/emergency start.

3.6.3.5 Timing Marks Accessible and easily read timing marks shall be provided to permit checking of valve and injection pump timing. Means for timing and jacking the engine over by hand shall be provided.

3.6.3.6 Crankshaft Provisions shall be made on the SAC end of the crankshaft for attaching a torsiograph drive.

3.6.3.7 Crankcase Fumes A closed system to dissipate oil fumes generated by the engine in the crankcase and other areas through the engine intake or exhaust system shall be provided. Engine shall operate with a neutral or negative crankcase pressure. Recovered fumes shall not have an effect of increased engine maintenance.

3.6.3.8 Engine Crankcase and Air Box Explosion Relief Devices Explosion relief valves are to be installed on enclosed crankcases of all engines having a cylinder bore exceeding 200 mm (8 inch) or having a crankcase gross volume exceeding 0j.6 m^3 (31 ft^3).The free area of each explosion relief valve is not to be less than 45 cm^2 (7 $in.^2$), and the total free area of all relief valves is to be not less than 11,500 mm^2 (7 $in.^2$ for each cubic meter (ohne square inch for each two cubic feet) of crankcase gross volume. The volume of the fixed parts in the crankcase may be deducted in estimating gross volume. The engine shall be provided with spring loaded relief devices(s) to provide relief of crankcase pressure due to crankcase explosion. Relief of gases shall be directed downward from the crankcase. Relief device shall contain flame-arresting device, which will stop or contain emission of flame.

3.6.3.9 Intercooler If the engine requires an intercooler and or aftercooler, the Contractor may use the Government's existing heat exchanger rated for 710,000 BTU's/Hr. If this heat transfer capacity is not sufficient, the Contractor shall provide a suitable heat exchanger qualified for Naval use.

3.6.3.10 Fluid Piping Systems

3.6.3.10.1 Piping Engine-attached piping shall be strapped and supported by the engine structure. Take-down joints in fuel systems shall be avoided to the maximum extent possible. Connections from the engine to the ship piping system (such as exhaust, lubrication-oil and fuel-oil inlet and return, shall interface with piping components in accordance with Figures 1 through 11. Each engine flange connection shall have a companion flange for welding to the ship piping.

3.6.3.10.2 Tapered Pipe Threads Tapered pipe threads shall be avoided to the maximum extent possible in engine piping systems, accessories, or driven equipment. Thread connections, where used in hardware specifically designed for this generator set, shall employ straight threads in accordance with SAE J1926 except as provided below. Tapered Pipe threads are permitted in the following areas:

a. Pipe plugs in sizes of ¾ inch and below used for applications where design pressures do not exceed 50 psig. Plugs shall be seal welded or brazed, where removal is not periodically required.
b. Instrumentation, controls, vent, filling and drain connections where design pressures do not exceed 50 psig and where fluids handled.

    (1) are not toxic
    (2) are not dangerous
    (3) would not cause atmospheric contamination
    (4) would not create a fire hazard; and
    (5) which would not cause, in the event of failure, a major breakdown of equipment nor create a hazard to the surrounding area nor affect the operation of other vital equipment

c. Pipe plugs internal to the engine

3.6.3.10.3 Flexible Hose Flexible hose used on the engine shall meet the fire resistant requirements of 30CFR 18.65. Hose identification shall be embossed and shall include the manufacturer's name, part number, hose size, rating and date of recommended replacement. Hose shall not be painted. Flexible hose assemblies provided that are not normally supplied with the engine shall be in accordance with NAVSEA Technical Publication S6430-AE-TED-010.

3.6.3.11 Cooling Water Pumps

3.6.3.11.1 Jacket Water/Intercooler Pump The jacketwater and intercooler/aftercooler (if required) pump if equipped shall be an engine-driven centrifugal type. The drive arrangement shall prevent water leakage into the engine lubrication oil system. The jacket water pump shall have a vent system to remove system gases transferred to the pump or mechanically scrubbed by the pump that accumulate in the eye of the suction and the casing. The pump shall be provided with means to completely drain the pump without the use of special tools.

3.6.3.11.2 Jacket Water Temperature Control Jacket water temperature regulator devices and thermostatic devices shall be either the fail safe type which will pass all the cooling water through the cooler in the event of failure of the thermostatic element or shall be provided with a manual "override" for the thermostatic element.

3.6.3.12 Fuel System The fuel system shall include the following:

a Fuel pump relief valve connected to discharge into the fuel pump suction or the clean fuel supply tank
b Fuel pump (hand pump and fuel feed pump)
c Fuel priming pump (manual only)
d Duplex fuel filter
e Necessary piping, valves, and fittings to interface with attached fuel pump

3.6.3.12.1 Fuel Leak-Off Clean leak-off from the fuel injection components, and fuel injection pumps shall be returned to the clean fuel supply tank.

3.6.3.12.2 Fuel Pump The fuel feed pump shall be a positive displacement fuel pump which is engine-mounted and engine-driven. The fuel pump shall be capable of providing a minimum suction lift of 15 inches Hg.

3.6.3.12.3 Duplex Fuel filters The engine fuel system shall have a duplex fuel filter. The duplex fuel filter shall consist of two filter units with a transfer valve and disposable filter elements. Drop-in or spin-on filter elements may be supplied connected to a common head or piped together. Filter housings for drop-in elements shall be constructed of metals that are not readily corroded by seawater contaminated fuels. The valve shall direct flow through one side to the other side without interrupting flow. Each side shall be sized to accommodate the full-flow fuel supplied to the engine fuel manifold supply line or supply header with an appropriate margin at rated engine load and speed. Each side shall employ manually operated drain valves to drain filter bodies. Tapered pipe threads shall not be used. Filter transfer valve and vent design shall not change generator output during replacement filter installation, filling or venting. The Contractor shall provide the Government with interface information for the vent and drain valves.

3.6.3.12.4 Fuel-Oil Priming Pump A fuel-oil priming pump shall be furnished. The priming pump shall be capable of priming the engine fuel oil system within two minutes following a filter service (change) at an ambient temperature of 70 degrees F. The pump shall be manual operated.

3.6.3.13 Lubricating System The lubricating oil shall conform to MIL-MIL-PRF-2104. The engine shall be provided with an oil level indicator, oil level sensor, sampling valve, fill opening, and accessible sump drain connection or a sump pump to drain or clean the engine oil pan. Bayonet type oil level indicators shall be shielded to permit accurate readings while the engine is running. The boyonet indicator shall be fitted with a retaining chain or cable. The sump shall contain a capacity to allow for 1000 hours between oil changes using time based criteria. Spectrographic limits and guidance for wear metals shall be provided to allow condition based oil monitoring. A location in the lube oil system shall be provided to allow for flushing.

3.6.3.13.1 Lubricating-Oil Pumps Pressure pumps, scavenging pumps and piston cooling oil pumps, if required, shall be of the positive displacement type. Lubrication oil pumps shall be driven by the engine. The primary engine scavenging pump shall scavenge the system from idle to rated speed including oil returned from Kato generator bearings. A relief valve shall be provided for the outlet of each pump. If the pump suction incorporates a check valve, means shall be provided to prevent excessive pressure build-up in the suction line in case the engine and pump are rotated backwards.

3.6.3.13.2 Coolers The lubricating oil cooler shall be jacket-water cooled and attached to the engine.

3.6.3.13.3 Lubricating-Oil Filters Engines shall have a full-flow filter and may have a bypass oil filter. Provisions shall be made to measure the pressure drop across the filter unit. The filter inlet shall be internally baffled or so constructed as to prevent the oil flow from impinging directly on the filter elements. Provisions shall also be made for draining the filter elements during maintenance to a bilge funnel drain.

3.6.3.13.3.1 Full-Flow Filters The filter unit shall have a relief valve that shall bypass oil when the pressure drop exceeds the engine manufacturer's recommended limit across the elements and shall pass the full oil flow of the lubrication oil pump. The filter housing shall have a manually operated drain valve which shall completely drain the filter for servicing. Manually operated vent valves shall be provided for the expulsion of air. The Contractor shall provide the Government with interface information for the vent and drain valves.

3.6.3.13.4 Lubrication-Oil Strainers Strainers shall be located on the suction side of each lubrication pump.

3.6.3.13.5 Lubricating-Oil Prelube System Engines shall have a Government furnished manually controlled, lubricating-oil priming pump that shall prime the engine within 4 minutes at a lubricating-oil temperature of 55 degrees F. This pump shall not be required for normal engine operation.

3.6.3.14 Air Intake Systems The engine will take combustion air from Shipbuilder furnished natural vent air ducting directly to the generator compartment. An air screen is installed in the ducting to the compartment. The Contractor shall provide any additional filtration upstream of the turbocharger compressor inlets as he believes is necessary to ensure trouble-free operation of the engine's intake components. The Contractor shall provide details of this filtration system configuration to the Government so that the Government can ensure access for maintenance. Filters shall be provided with maintenance indicators. The filters provided by the Contractor shall either be capable of passing smoke laden air without requiring replacement, or shall be readily removable to facilitate passing smoke laden air in an emergency. Charge air coolers if fitted, shall be jacketwater or separate circuit cooled. Separate circuit, if fitted, shall be cooled by freshwater treated with NALCOOL 3000. Under no circumstances will seawater be allowed on any engine circuit.

3.6.3.14.1 Blowers and Air Receivers Means shall be provided for draining pockets in the blower housing and air receiver where oil or water may accumulate (if blowers are applicable).

3.6.3.15 Exhaust System The exhaust system shall be sealed to prevent exhaust gas from leaking into the engine compartment and shall have a permanent pressure tap for measuring exhaust back pressure that is normally closed and labeled. The engine shall be flanged to accept an expansion joint (not supplied by the Contractor) between the exhaust manifold or turbocharger outlet and the ship exhaust piping. Exhaust system components shall be either jacket-water cooled, insulated, or shielded as required. Asbestos shall not be used. Provisions shall be made for draining the gas spaces of the manifold from either end.

3.6.3 15.1 Exhaust Emission The Contractor shall provide documentation that the engine has been tested by the manufacturer at the proposed rating for gaseous and particulate emissions and in compliance with MARPOL Annex VI Regulation 13 in effect at the time of contract solicitation. Documentation shall be provided at the time of submission of proposal.

3.6.3.16 Overspeed Protection The engine shall be provided with ECU controlled speed limiting devices and redundant overspeed shutdown devices. The overspeed shutdown device which operates at the lowest speed shall be for the Table I, Item 8. This shutdown device shall be independent of any ECU. A method of testing the overspeed shutdown devices shall be provided. Operation of any overspeed shutdown device shall reduce fuel injection to zero and shall initiate securing of combustion air inlets. Air inlet shutoffs shall require manual resetting after actuation. Electronic resetting shall be via activation of Table I, Item 12. Overspeed limiting shall be set at 107 to 110 percent of 1800 rpm. ECU overspeed shutdowns shall be set at 114 to 115 percent. Independent overspeed shutdown Table I, Item 8 shall be set at 111 to 113 percent.

3.6.3.17 Diagnostic Capability Diesel engine shall be fitted with (or be capable of being fitted with an onboard machinery diagnostics/prognostics system. If capabilities are under development, present a plan to test, demonstrate, validate and then retrofit the diagnostics/prognostics technologies. The diagnostics/prognostics system shall be capable of both forward and back fit and be built in compliance with the Open System Architecture for Condition Based Maintenance (OSA-CBM) standard maintained by the Machinery Information Management Open Systems Alliance (MIMOSA). Diagnostics sensors shall be wired or wireless, self calibrating (where appropriate), capable to self-test, distributed diagnostics processing (where necessary) and include self-description in the form of a Transducer Electronic Data Sheet (TEDS).

3.6.3.18 Instrumentation The Contractor shall furnish a local engine mounted instrumentation panel. This panel is located in a normally unmanned space but shall contain a display or displays that can be used to monitor engine parameters and ECU inputs and outputs for trouble shooting and maintenance purposes. The panel shall also have indicators to show the status of the Secondary ECU if active and ready. A red Emergency Stop Switch shall also be provided on the panel. After actuation the switch shall require manual resetting. Activation of this switch while the engine is running shall initiate fuel shutoff and air inlet shutoff. A contact from this switch shall also be provided in accordance with Table I, Item 22. The instrumentation panel shall contain internally: protected circuits, engine lockout control switch, relays, timers, and meter control circuits. This panel shall receive signals from the interface/connection box necessary for operation with the Government supplied LOCOP and Switchboard components. The display on the Local Engine Mounted Instrumentation Panel shall be capable of displaying the following parameters:

a. Lube oil pressure to engine
b. Combined exhaust temperature
c. Engine Speed
d. Crankcase press
e. Unfiltered oil press
f. Filtered oil press and temperature
g. Filtered fuel press
h. Unfiltered fuel press
i. Ambient air press
j. Coolant Temp
k. After cooler coolant temp
l. Turbo charger inlet press (left and right if two)
m. Turbo charger outlet press
n. (24 VDC) System voltage

3.6.3.18.1 Thermocouples and Cabling Thermocouple cable AWG16 Type TCKX-1 or LSTCKX-1 will be provided by the Government. The Contractor shall provide one Type K thermocouple per engine cylinder with connectors and mating connectors suitable for this cable type or thermocouples with connection heads for making connection with the cable (Table I Item 19). The Contractor shall provide cableway hangars to support his cable and a diagram indication the cylinder numbering scheme of the supplied engine. The common exhaust thermocouple shall also be Type K and shall be provided by the Contractor (see Table I, Item 20).

3.6.3.19 Operational Control System Controls necessary for operation of the engine by an operator outside of the engine enclosure will be provided by the Government. The control shall interface with the existing LOCOP and Switchboard mounted components to control the Contractor furnished engine and engine controls. A Contractor furnished interface/connection box shall be provided to convert existing LOCOP signals to signals compatible with the Contractors engine control system. The interface/connection box shall also act as a connection box for Contractor furnished interfaces (other than Power and thermocouples) to Governments systems (see Figure 13 and Table I).

3.6.3.19.1 Emergency Shutdown Device The engine shall have an inlet air emergency shutdown device, operable by a pull cable and electrically by solenoid(s) that reduces fuel injection output to zero, shuts off induction air, and stops the engine within 15 seconds without any damage to the engine or its driven equipment. The device shall require manual resetting before the engine can be restarted. The pull cable, sheaths, guides, pulleys, handles and hardware shall not be constructed of any materials that would burn, melt, or render the control inoperable in case of fire. The Government will supply all cable(s) necessary to connect to the Contractor provided single engine attachment point.

3.6.3.20 Interface Signals The Contractor shall provide and operate with signals in accordance with Table I. The Contractor shall propose and the Government shall approve the type of signal to be used.

3.6.3.21 Instrumentation Connection Points Tapered pipe threads used as instrumentation connection points, shall have adapters so that the engine shall use root connectors, root valves, and instrument isolation valves as specified in MIL-V-24578 for pressure indication points. Thermowells shall be provided as specified in MIL-T-24270 or by the engine manufacturer.

3.6.3.21.1 Instrument Range The temperature and pressure ranges and/or alarm switch set points for each parameter shall be identified. In addition, it is the Contractor's responsibility to identify other parameters that will require monitoring in order to provide for safe operation of the diesel engine.

3.6.3.21.2 Instrument Installation Instruments shall be installed such that the connecting cabling can be suitably connected, supported and protected.

3.7 Electromagnetic Interference Requirements

3.7.1 All Contractor Furnished Electrical and Electronic Equipment shall be designed and tested to meet the requirements of MIL-STD-461E Tests CE102, CS101, CS114, CS116, RE101, RE102, RS101, RS103 (18,000 MHZ) for surface ship, metallic hull below deck. In addition, the governor system shall be subject to MIL-STD-461C Tests CS06, RS02 (Part I: Magnetic Induction Spike Test).

4 TESTING AND QUALITY ASSURANCE

4.1 Responsibility for Inspection The Contractor is responsible for the performance of all inspection and test requirements as specified herein. The Contractor may use any facilities suitable for the performance of the inspection and test requirements specified herein. The Government reserves the right to perform and/or witness any of the inspections set forth in this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements. Before proceeding with the testing of an engine as required by this section, the Contractor shall notify the Government in writing that witness is desired during testing. Such notice shall contain all the necessary information for identification of the engine, test schedule and agenda and test location.

4.1.1 Responsibility for Compliance All items shall meet all requirements of this specification except as approved by Government. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program for this component. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements; but this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

4.1.2 Inspection System The Contractor shall provide and maintain an inspection system acceptable to the Government for supplies and services covered by this specification . An ISO 9000 compatible inspection system is required. The quality assurance system shall be documented in the contractor's Quality Assurance Program Plan (QAPP). The QAPP shall include as a minimum the following:

a. Contractor responsibilities
b. Documentation and records
c. Corrective action
d. Measuring and test equipment, and calibration requirements
e. Process controls
f. Non-conforming materials
g. Sampling inspection
h. Inspection provisions
i. Receiving inspection

4.2 Classification of Inspections The inspection requirements specified are classified as follows:

a. First Article Inspection
b. Quality Conformance Inspection

4.3 Test Agenda A complete test agenda and procedure shall be submitted to the Government for review and approval prior to the start of any tests. This agenda shall list all tests to be conducted on the individual units and assembled generator sets. Each test shall be identified by the applicable specification showing paragraph number and title of test. The agenda shall indicate where and when each test is to be conducted.

4.4 Test Reports Test results shall be recorded on test forms prepared by the Contractor.

4.5 First Article and Quality Conformance Inspections The engine shall be subjected to the examinations and tests specified in Table A-I, Appendix A and Table B-1 of Appendix B.

a. First article inspections are performed on the first unit only.
b. Quality conformance inspections are performed on all units.

4.5.1 Standard Test Conditions

4.5.1.1 Test Operating Condition The DG set shall be subjected to the operating conditions specified in Table IV for all tests unless other wise specified.

4.5.1.2 Power Correction Power correction in accordance with ISO Standard 3046 shall be applied to power measurements.

Engine operation at the target load specified in any test shall be achieved by adjusting the observed load until the corrected value of the observed load is within plus or minus 1 percent of the target specified load. The 100 percent, full-load, corrected bhp shall equal or exceed the proposed rating for the test.

4.5.1.3 Restriction Settings Inlet air and exhaust system restrictions shall be measured at locations in accordance with SAE J1349. The restriction values specified in Table VII shall be set by adjusting restrictions devices installed in the inlet air and exhaust systems for all tests unless otherwise stated.

Table IV

TEST STANDARD OPERATION CONDITIONS

Items	Variable	Test Standard and Operating Range Limits
a	Inlet air temperature[1/] (degrees F)	120 degrees F maximum[2/]
b	Barometric inlet air pressure dry[1/] (in. Hg)	29.92
c	Fuel oil temperature for engine (degrees F)[3/]	110 maximum
d	Inlet air system restriction (vacuum) after filter[1/] (in. Hg – total)	1 minimum inches Hg
e	Exhaust system restriction (total)	27.0 inches H_20 minimum

Notes:

1/ Measurement locations for these specified conditions shall be in accordance with SAE J1349.

2/ These standard condition values shall be used within the power correction when this correction formula is applied.

3/ If the engine is equipped with a fuel oil cooler, this specified condition shall apply after the filter.

4.5.1.4 Test Fluids The diesel fuel and lubricating oil used during the tests shall be in accordance with MIL-F-16884 and MIL-PRF-2104, respectively. The corrosion inhibitor used during testing shall be NALCOOL 3000.

4.5.2 Examinations Prior to the commencement of tests, the following examinations shall be performed.

4.5.2.1 Measurement Standards The wear limits for all wearing engine components, limits for all running clearances and adjustments, design tolerances and clearances, engine operating parameters, maximum loads for speeds between idle speed and rated speed, and lubrication-oil spectrographic analysis limits shall be determined prior to any testing required by Appendix A and Appendix B. Use of manufacturers published guidance for reusability will be allowed if wear limits do not exist for specific parts.

4.5.2.2 Visual and Dimensional Evaluation The engine shall be subjected to a visual and dimensional examination to ensure that the material, design, workmanship, and construction are in accordance with the requirements of Appendix A and Appendix B.

4.5.2.3 Evaluation Criteria The failure of any component to meet the requirements of this specification appendices,reusability guidance, the contractor's design tolerances and clearances, or evidence of manufacturing defects shall be cause for the rejection of the engine.

4.6 Additional Tests

4.6.1 Weight and Center of Gravity The engine set and all detached accessories shall be weighted dry. The center of gravity of the DG set shall be determined by actual measurements.

4.6.2 Shock Qualification The engine set, including the engine, generator, subbase, instruments, controls, all attached and unattached accessories, shall be tested or qualified to the requirements of MIL-S-901. At the contractor's discretion, similar or identical equipment that has been tested in accordance with MIL-S-901 requirements, may be submitted for shock extension. Such submissions shall be made to the procuring activity and shall include the Navy approval letter and detailed proof of testing. Components that cannot be extended must meet the shock test requirements of MIL-S-901D.

4.6.3 Shock Testing Requirements The engine and supplied components shall be High-Impact, Grade A shock tested in accordance with MIL-S-901D..

5 PRESERVATION AND PACKAGING FOR SHIPMENT

5.1 Preservation Method of Preservation of the engine shall be as specified by the Contractor and approved by the Government. All contract equipment shall be preserved for storage of one (1) year (minimum). The Contractor shall provide the Government with a long-term preservation plan for the engine. The fluid system preservation used in the engine lubricating oil system shall be miscible in the engine lubrication oil, and shall not require flushing with special solvents for removal. External machined surfaces shall be coated with P-2 preservative and protected from mechanical damage.

5.2 Packaging Standard commercial practices shall be utilized. Packaging shall be suitable for outdoor storage for up to one year. Diesel engine components shall be packaged so as to avoid damage during transport and handling. Piping system interfaces shall be protected with plastic or metal covers. Use of fibrous covers such as wood or fiberglass is prohibited. Where desiccant bags are provided in the generator and control equipment they shall be physically tied together by a lanyard such that they will all be removed together. A humidity indicator shall be taped to the inside of each cover behind which desiccant bags are installed. .

5.3 Packing See section D.

5.4 Marking

5.4.1 Shipping Containers Shipping containers shall have the following markings:

a. "STORE RIGHT SIDE UP – WARNING SEE UNPACKING INSTRUCTION."
b. Apply adjacent to the identification marking on the side of the container "CAUTION – THIS EQUIPMENT MAY BE SERIOUSLY DAMAGED UNLESS UNPACKING INSTRUCTIONS ARE CAREFULLY FOLLOWED. UNPACKING INSTRUCTIONS ARE LOCATED (state where located)."
c. "REUSABLE INTERIOR AND EXTERIOR CONTAINER (when applicable)."
d. Handling and structural markings as applicable (see MIL-STD-129 and appendix to MIL-C-104).
e Quantity and location of desiccant bags shall be clearly indicated by markings on generator set and control equipment covers.

5.5 Special Instruction

5.5.1 Preserved Units The engine preserved in accordance with Paragraph 5.1 shall be tagged as follow:

a. The fluid systems of this engine have been preserved with (Contractor provided information).
b. Depreservation of the diesel engine fluid system shall be in accordance with (Contractor procedure number).

5.5.2 Depreservation The Contractor shall provide a depreservation procedure for Government review and approval. The Contractor shall provide any additional depreservation instructions for systems or accessories when such instructions would be necessary due to design peculiarities of his equipment. Instructions shall be packaged in a transparent waterproof plastic bag, minimum 4 mil thick along with a copy of the Government approved depreservation procedure. Closure shall be by heat sealing. The shipping container in which the instructions are packed shall be marked to so indicate.

5.5.3 Unpacking Unpacking instruction shall be provided for complex equipment or systems.

5.5.4 Technical Manuals The technical manuals shall be packed and shipped separately using best commercial practices to ensure safe delivery.

6 RELIABILITY AND MAINTAINABILITY REQUIREMENTS The Contractor shall provide a standard warranty for the engine for a minimum period of one year from the activation aboard ship.

6.1 Operational Requirements The engine shall have a life expectancy of 66,000 hours of operation with no limitations as to the number of starts and stops. The time between major overhauls shall be not less than 20,000 hours.

6.2 Reliability and Maintainability (R&M) Requirements The Mean Time Between Failures (MTBF) shall be at least 1200 hours. The Mean Time to Repair (MTTR) shall be no more than 5 hours.

6.3 R&M Analysis

6.3.1 RMAAA Requirements A R&M Allocation, Assessment, and Analysis (RMAAA) shall be performed. The Contractor can satisfy the requirements of this paragraph by preparing the RMAAA in accordance with MIL-STD-785, Task 201, 202, and 203, and MIL-STD-756, Task 102, Method 1001 and Type III Prediction using Task 202, Method 2005, MIL-STD-470, Tasks 201, 202, 203, and 205 and Procedure II of MIL-HDBK-472 (maintainability) or by use of a commercial reliability standard as pre-approved by the Government. Analyses shall include reliability block diagrams, maintainability design criteria, mathematical models, predictions, assumptions, and definitions of failure (see Section 6.5) sufficient to permit an R&M evaluation of the design by the Government. Reliability block diagrams shall include items at a level of indenture at least two levels below that for which the prediction is being made. Predictions shall be made for Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR). If the predicted value is worse than the required value, R&M allocations shall be performed and the design shall be modified in order to meet the required value. Failure data from fleet experience with designs and stress levels similar to the FFG 7 Class shall be used. When such data are not available, electronic part failure rates shall be obtained from MIL-HDBK-217F. Similarly, mechanical part failure data, adjusted as necessary for FFG 7 Class stress levels, may be obtained from the Rome Air Development Center, Rome, New York, (RADC) NPRD-95 'Nonelectronic Parts Reliability Data", or other valid source, as pre-approved by the Government. A RMAAA report shall be prepared and shall include recommended R&M improvements.

6.3.2 Waiver of RMAAA Requirements The RMAAA may be waived at the discretion of the Government if the plant and its components being offered are identical to equipment that has been fully tested and examined previously and, following review of the previously prepared FMECA, is found to be in accordance with the requirements of Paragraph 6.2

6.4 Failure Mode, Effects, and Criticality Analysis

6.4.1 FMECA Requirements A Failure Mode, Effects, and Criticality Analysis (FMECA) shall be performed. The Contractor can satisfy the requirements of this paragraph by preparing the FMECA in accordance with MIL-STD-1629, Tasks 101, 102 (quantitative approach), and 103, MIL-STD-785, Tasks 204, 208 and MIL-STD-470, Task 204) or by use of a commercial reliability standard as pre-approved by the Government. Failure data from fleet experience with designs and stress levels adjusted to FFG 7 Class shall be used. When such data are not available, electronic part failure rates shall be obtained from MIL-HDBK-217F. Similarly mechanical part failure data, adjusted as necessary for FFg 7 Class stress levels, may be obtained from the Rome Air Development Center, Rome New York, (RADC) NPRD-95 "Nonelectronic Parts Reliability Data" or other valid source as pre-approved by the Government. The FMECA is a procedure to identify, evaluate, and analyze all known potential failure modes, including the causes and the proposed actions to inhibit such failures or reduce their criticality. All detection mechanisms and backup means of operation for a given failure mode shall be identified. Similarly, for all single-point failure modes (no backup means exists in the design), any compensating provisions, such as failure indicators, fail safe features, securing mechanisms, and alarms shall be identified. Where there are no adequate compensating provisions for single point failure modes, the Contractor shall provide justification for their lack or recommend adequate compensating provisions. The FMECA shall be performed at the initial indenture level and down at least two additional levels of indenture. A FMECA report shall be prepared and shall include recommended R&M improvements. The time interval considered in the FMECA shall be the Engineered Operating Cycle Time (EOC), which is the time between regular overhauls of the equipment or system. This time interval is considered 10,000 hours.

6.4.2 Waiver of FMECA Requirements The FMECA may be waived at the discretion of the Government if the plant and its components being offered are identical to equipment that has been fully tested and examined previously and, following review of the previously prepared FMECA, is found to be in accordance wit the requirements of Paragraph 6.2

6.5 Failure Reporting

6.5.1 Failure Reporting Requirements A Failure Reporting and Analysis program shall be established. The Failure Reporting requirements apply to all equipment procured by this specification. The reporting requirements shall commence when equipment undergoes any test activity and shall continue through end of warranty. The requirements shall include:

a. Documentation of all malfunctions according to the following definition:
   (1) Malfunction event – an event in which an item does not perform its intended function, regardless of impact on equipment or system performance or the method and duration of restoration.
b. Analysis of each malfunction or technical problem with emphasis on pattern malfunctions to include identification of repaired, replaced or adjusted item, circumstances surrounding the malfunction, malfunction symptoms, and probable cause of malfunction.
c. Classification of malfunction events as failures or non-failures according to the following definitions:

   (1) Failure: Any malfunction or combination of malfunction that prevent equipment from operating in one or more modes of operation in accordance with the performance requirements.
   (2) Non-Failure: Any malfunction or combination of malfunctions that is not classified as a failure shall be classified as a non-failure.

d. Classification of failure based on its relevancy. Relevant and non-relevant failure definitions shall be as specified in MIL-STD-781C dated 21 October 1977 (Change Notice 1 does not apply), modified as follows:

   (1) Typical relevant failures are

      (a) Design defects
      (b) Manufacturing defects
      (c) Parts defects
      (d) Unknown
      (e) All other categories not specifically listed as non-relevant

(2) Typical non-relevant failures are:

(a) Accidents, mishandling, or improper storage after installation check-out.

(b) Operator or procedural error (provided documentation errors are promptly corrected and verified by the Contractor).

(c) Installation or maintenance errors due to drawing error implementation (provided documentation errors are promptly corrected and verified by the Contractor).

(3) In addition to the above classification criteria, the following apply:

(a) Failure due to wrong or missing parts is relevant unless clearly in a non-relevant definition.

(b) A transient failure that is non-repetitive and does not require repair is non-relevant. The second such failure and any additional failures of this type shall be considered relevant. Failure of a serial or redundant item, as the direct result of failure of another serial item, is non-relevant. However, a failure of a redundant item that causes failure of a series item or the entire redundant function shall be considered a relevant failure. Failures are not multiple unless they are independent.

e. Statement for each malfunction of the immediate corrective action and recommendation, if different, for permanent corrective action.
f. Verification that corrective action has been implements in applicable source control drawings, maintenance manuals, and other technical data.
g. Analysis of maintainability problems to determine required corrective actions, such as, equipment design change to improve accessibility, repair time, frequency of failure, or documentation.
h. The Contractor shall participate in a Government's failure review board.
i. Failure Summary Reports shall prepared.

Appendix A
First Article Inspection and Test Requirements

1. General

1.1 The engine shall be subjected to the first article inspection and tests specified in Table A-1 of this appendix to establish and validate the engine rating approval. The finished unit shall be subjected to endurance test hours to validate the proposed engine testing.. The rating established by this approval test shall be based on the maximum ambient conditions stated in section 3.2.1.2 of the Purchase Specification. The Government reserves the right to have a representative on site during part or all of the testing. A test schedule and agenda shall be provided to the Government for approval prior to the start of testing.

1.2 The engine test facility shall be suitable to perform all testing; providing instrumentation, power generation and controls as required by the Purchase Specification, and data recording capability. Data shall be measured and recorded when testing the engine at various load points and shall include all necessary parameters for the engine operation. Readings shall be taken and recorded at a maximum interval of one hour with at least one reading taken during each step after the data stabilizes. All data, including written logs, shall be available for inspection by the Government during the full course of the test. Additionally, a written log shall be maintained showing all preventive and corrective maintenance actions performed during the course of the tests.

1.3 Some tests are conducted with the generator set. The evaluation of the tests set forth are intended for the engine and the equipment supplied to interface it with the existing generator set. Failure or non compliance of an existing component or system from the generator set is not grounds for failure of the supplied equipment unless it is a secondary failure resulting from an initial failure or incompatibility of the supplied equipment.

2. Inspections before first article tests

2.1 **Measurement Standards, Visual and Dimensional Evaluation**: An engine material condition baseline shall be established prior to the start of testing which will support the post testing inspection requirements in accordance with the Purchase Specification and Table A-4 of this appendix. The material condition baseline shall include measurement of all parts to be presented for inspection following testing to establish the original assembled condition of the engine. Baseline limits and expected wear limits shall be provided to the Government prior to the start of testing.

2.2 **Evaluation Criteria**: The failure of any component to meet the requirements of this appendix, or evidence of manufacturing defects shall be cause for the rejection of the engine. Parts that do not meet the manufacturer's design tolerances and clearances shall be cause for rejection of the engine unless they have been found acceptable for installation in accordance with the manufacturer's quality assurance procedures for variance of new parts.

3. Standard first article test conditions

3.1 **First Article Test Operating Conditions**: The engine shall be subjected to the operating conditions specified in Table IV of the Purchase Specification. Means shall be provided to maintain these test conditions as closely as feasible.

3.2 **Test Fluids**: The diesel fuel, lube oil and coolant corrosion inhibitor used during testing shall be in accordance with the Purchase Specification.

4. Operation Criteria

4.1 **Engine monitoring**: Engine operation shall be monitored throughout each test. Instrumentation and data required to be recorded will be included in the Seller's test procedure and provided for approval. The parameters of Table A-3 shall be measured and recorded at each operating condition at which the diesel set operates for at least 10 minutes.

4.2 **Engine Modification**: From the start of test, no parts shall be modified, replaced, or adjusted (except for scheduled maintenance).

4.3 **Engine Shutdowns**: Engine shutdown during the endurance test shall be defined as either permissible shutdowns or forced shutdowns. The Government shall be notified of engine shutdowns, both permissible and forced, with the exception of the 10-minute minimum shutdown between test cycles. In addition, the engine shall be shut down if one or more of the following conditions occur.

a. Abnormal operation or failure of an engine component.
b. Engine misfire during any test cycle operating condition.
c. Engine operation outside of operating parameters as defined in the Purchase Specification.
d. Engine torque or speed exceeding acceptable range of variability.
e. Lubricating oil exceeding any physical test condemning limit.
f. Test personnel or engine endangered.
g. Faulty test cell service systems or other systems extraneous to engine.

4.4 Permissible Shutdown: Permissible shutdowns include the minimum 10 minute shutdown period at the end of each cycle. Scheduled maintenance shall be performed during this shutdown period. A shutdown shall be classified as permissible only if it cannot be described by any of the forced shutdown criteria.

4.5 **Forced Shutdowns**: An engine shutdown shall be classified as a forced shutdown if it can be described by one or more of the following.

a. A single failure of an engine component that cannot be corrected or repaired within a 2-hour period (if the engine shutdown occurred during off-hours, initiation of the repair may be delayed until the start of the next work day. Additionally, a 24 hour logistic down time will be allowed to attain component.
b. Two failures of the same primary engine component.
c. Engine repair requiring access to the internal crankcase components or gear train; or requires the removal of manifolds, blowers, or cylinder heads.
d. Failure to maintain engine operation within the variability limits of the operating parameters, target torque, or target speed; or failure to maintain lubrication oil from exceeding the condemning limits of the physical tests.
e. Any failure related to a design, manufacturing, or quality assurance discrepancy.
f. A part or assembly is replaced.

When a forced shutdown occurs, the endurance test shall be terminated. If the Government determines the cause of shutdown to be a design, manufacturing, or quality assurance discrepancy, correction of the discrepancy and modification of the engine shall be required before endurance testing is resumed. Re-commencement of the entire endurance test shall then be required.

5.0 Qualification tests to be performed during First Article Test

The various tests to be conducted as part of the First Article Test qualification including the endurance test are listed in Table A-1.

5.1 **Engine starting**: The following tests shall be conducted using the automatic mode.

5.1.1 **Normal Starting**: Nine consecutive starts shall be made under normal ambient conditions. The average time required to start the unit, and the minimum starting rpm shall be determined. The engine shall fire and continue operating within 5 seconds after the starting mechanism is engaged.

5.1.2 The following data shall be obtained for air starting:

a. The minimum quantity of air expressed in cubic feet of free air at 14.7 psia and 68°F. for the cold start.
b. The minimum quantity of air expressed in cubic feet of free air at 14.7 psia and 68°F. necessary for 10 successive starts, including the cold start.
c. The minimum air pressure at which the unit will start within the five second time limit.

Table A-1
First Article Tests and Inspections

Test Description	Test Method	Hardware Level
Engine Starting	5.1	Diesel Gen. Set
Torsional Vibration	5.2	Diesel Gen. Set
Piping Integrity	5.3	Diesel Engine
Fuel Consumption Test	5.4	Diesel Engine
Emergency Shutdown	5.5	Diesel Gen. Set
Overspeed Protection Device	5.6	Diesel Engine
Exhaust Emissions	5.7	Diesel Engine
Lubrication Oil Consumption	5.8	Diesel Engine
Fuel Oil Analysis	5.9	Diesel Engine
Lubricating Oil Analysis	5.10	Diesel Engine
Spectrographic Analysis	5.11	Diesel Engine
Physical Analysis	5.12	Diesel Engine
Cooling Water Analysis	5.13	Diesel Engine
Endurance Test	5.14	Diesel Engine
Inclined Operation	5.15	Diesel Engine
Governor System	5.16	Diesel Gen. Set
Black Start	5.17	Diesel Gen. Set
No Break Power Supply Test	5.18	Diesel Gen. Set
Electromagnetic Interference Characteristic Tests	5.19	Diesel Engine

5.2 **Torsional Vibration**: The diesel generator set shall be tested in accordance with the requirements of MIL-STD-167-2 for type III vibration

5.3 **Piping Integrity**: The maximum working pressure (lb/in^2) and maximum leakdown rates (lb/in^2 –hr) of the various fluid piping systems external to the engine block, but not provided as standard equipment with the engine or generator, shall be determined. These systems shall then be tested at 150 percent of the maximum working pressures. Piping systems need not be completely assembled to accomplish this testing. These tests shall be carried out at room temperature using the fluids (lubricating oil, fuel, jacket

water, seawater, or air) that are contained n the various sections of piping during engine operation. For each fluid piping system the leakdown rate shall be determined by measuring the pressure at the start of the test and after 1 hour.

5.4 **Fuel Consumption**: Fuel mass flow measurements shall be made at a minimum of all all data points outlined in table A-2. Once engine temperatures and fuel flow have stabilized at each engine operating condition, three fuel mass flow and other measurements shall be made. The test results shall be used to produce a fuel map.

5.5 **Emergency Shutdown**: The emergency shutdown device (Paragraph 3.6.2.17.1 of the Purchase Specification) shall be operated, preceding the standard endurance test, with the engine stopped and following the last cycle of the endurance test with engine operational. The emergency shutdown device shall be actuated while the engine is operational as follows:

a. Once with the engine operating at no load and at a speed that is 10 percent greater than rated speed
b. Once with the engine operating at rated speed and full load

5.6 **Overspeed Protection Device**: Using local speed control, increase engine speed from idle to the overspeed trip set point of 2070 rpm (115 percent of rated rpm). This rpm traverse shall be completed between 30 seconds and 1 minute. A continuous measurement of rpm shall be made during the rpm traverse and for 30 seconds after the overspeed protection device is activated. Record the rpm at which the overspeed protection device functions, and the time required for the engine to come to a full stop.

5.7 **Exhaust Smoke Emission**: During the first four and the last four cycles, the engine exhaust smoke emission shall be continuously measured by any method contained in SAE J255. One smoke measurement shall be made at each engine operating condition in the 8-hour cycle.

5.8 **Lubricating-Oil Consumption**: Lubricating oil consumption shall be measured throughout the standard endurance test. An oil consumption test rig shall be connected to the engine lubricating-oil system, and oil quantity shall be measured during the first hour of every cycle. Alternative oil consumption measurement techniques, no less effective, will be considered. All additions or removals of lubricating oil from the engine shall be measured. Lubricating oil consumption rates shall be determined at approximately each 250 hours of testing or as recommended by the manufacturer.

5.9 **Fuel-Oil Analysis**: Two samples of fuel used for test engine operation shall be collected at the following times during endurance test hours. Before the use of each new lot of fuel, at 500 endurance test hours, and at 1, 000 endurance test hours. Samples shall be labeled. One sample of each pair of samples shall be saved, and the other shall be analyzed. The fuel analysis of the sample from each lot of fuel shall determine the following characteristics in accordance with each corresponding ASTM test method.

a. Lower heating value (ASTM D 240)
b. Kinematic viscosity (ASTM D 445)
c. Flashpoint (ASTM D 93)
d. Sulfur content (ASTM D 4294 or D 2622)
e. Ash content (ASTM D 482)
f. Carbon residue (ASTM D189 or D 524)
g. Total water content (ASTM D 1796)
h. Weight sediment (ASTM D1796)
i. Appearance (ASTM D 4176)

The fuel analyses conducted on all other samples consist only of tests for:

a. total water (ASTM D 1796)
b. Weight sediment (ASTM D 1796)
c. Appearance (ASTM D 4176)

5.10 **Lubricating-Oil Analysis**: Samples of lubrication oil shall be collected at the following times during the endurance test.

a. First cycle
b. Last cycle
c. After each ten test cycles
d The cycle preceding every lubricating-oil change

At each sampling time, two 8-ounce samples of lubricating oil shall be drawing from the test engine sampling valve during an idle operating condition immediately following one of the rated load and speed operating conditions of the test cycle. Two samples of unused lubricating oil shall also be taken from each lot of lubricating oil used during the test. Each time lubricating oil is added to or removed from the engine, the quantity added or removed shall be determined and recorded.

5.11 **Spectrographic Analysis:** Spectrographic analysis, of each lubricating-oil sample to be analyzed, shall be conducted to measure in ppm the concentration of oil additive elements and wear metal elements of oil-wetted components such as the following.

a.	Aluminum	h	Molybdenum
b.	Calcium	i	Nickel
c.	Chromium	j	Phosphorous
d	Copper	k	Silicon
e.	Iron	l	Silver
f.	Lead	m	Tin
g.	Magnesium	n	Titanium

The degree of accuracy of the spectrographic analysis shall be in accordance with the following table:

SPECTROGRAPHIC ANALYSIS

Items	Standard Reference Specimen (range in ppm)	Standard Deviation (maximum in ppm)
A	3 through 9	1.5
b	10 through 19	2
c	20 through 49	3
d	50 through 99	5
e	100 through 109	8
f	200 through 500	15

5.12 **Physical Analysis**: Physical analysis, of each lubricating-oil sample to be analyzed, shall be conducted in accordance with the indicated ASTM test methods in the following table:

ASTM TEST METHODS			
Items	Test	ASTM Number	Condemning Limit
a	Total base number	D 2896	0.002 oz KOH/oz minimum
b	Viscosity (at 100 degrees F	D 445	1190 Sus maximum and 465 Sus minimum
c	Fuel dilution – determined from flashpoint (if viscosity <605 Sus)	D 92	5.0 percent maximum or contractor's published limit, whichever is less
d	Water	D1744	0.3 percent maximum
e	Carbon residue 1/	D 189 or D 524	-
f	Sulphated ash 1/	D 874	-
g	Pentane and toluene insolubles 2/	D 893, procedure B	-

5.13 **Cooling-Water Analysis**: Two samples of cooling water shall be collected from the cooling system at the beginning and end of the endurance test and at intervals of 25 test cycles. Samples shall be labeled. One sample of each pair of samples shall be saved. The other sample of each pair shall be analyzed to determine inhibitor concentration.

5.14 **Endurance Test**: Reliability of the engine shall be demonstrated by a 1000 hour test broken down into 125 eight (8) hour test cycles with no failure. The eight hour test cycle is defined in Table A-2. The intake and exhaust restriction shall be set at 1 Hg and 3 psig respectively, at 100 percent load and speed. Fuel consumption and other data listed in Table A-3 shall be recorded during each eight hour cycle. The reliability test shall be completed in the following order.

a. 120 eight hour cycles as specified in Table A-2.
b. Two eight hour cycles at idling load and rated speed.
c. One hour cycle at no load and rated speed
d. Two eight hour cycles as specified in Table A-2.

The maximum allowable lapse time between steps or operating condition is 30 seconds. Each 8-hour cycle shall be followed by a minimum duration shutdown period of 10 minutes. The engine shall start and attain the first step or operating condition of

each 8-hour cycle within 60 seconds. Activation and stabilization of a preheat or keep-warm system, and the lubricating-oil priming system is allowed prior to starting.

Endurance testing can be waived by the government if the engine is essentially identical to an engine previously qualified by MIL-E-24455. Additionally, the previous qualification must be on an engine rated at the same or lower horsepower and brake mean effective pressure. Intent to request a waiver for this test shall be identified at time of proposal submission along with documentation to support.

Table A-2
Standard 8-hour Endurance Cycle

Step	Load (percent of load)	Speed (percent of rated)	Time (minutes)
1	100	100	120
2	85	100	60
3	0	Idle	10
4	25	100	110
5	0	Idle	10
6	50	75	30
7	0	Idle	10
8	60	100	10
9	110	100	120

5.15 **Inclined Operation:** The inclination test shall be made with the unit running at 60 Hz speed with or without load for at least 30 minutes in each of the following positions.

a. Shaft inclined, forward end down 7 degrees
b. Shaft inclined, forward end up 7 degrees
c. Shaft horizontal, base inclined to right 15 degrees
d. Shaft horizontal, base inclined to left 15 degrees

During the tests, the lubricating oil sump(s) shall be filled to the maximum operating level. It shall be ascertained that the mechanical balance is as good as it was in the horizontal position, that there is no pounding or grinding of the bearings, and that there is no leakage of oil or cooling water. A theoretical analysis and report may be substituted if mutually agreeable between government and contractor.

5.16 **Governing Systems:** The electric governing system for the diesel generator set shall meet the applicable performance test requirements specified in Table II of MIL-G-21410A.

5.17 **Black Start:** The purpose of this test is to ensure that the diesel generator set shall be capable of starting when there are no AC power sources available on the ship. Black starts shall be accomplished utilizing the Seller's DC no break power supply (NBPS) batteries as the power source. To perform the test, the diesel generator set shall be shutdown with AC power isolated to the LOCOP, NBPS (Table I, item 23 of the purchase specification), electric preheater (Table I, item 25 of the purchase specification). This will simulate a loss of all ships generator sources and the ship's centralized UPS. The generator set shall be started from the LOCOP utilizing the seller furnished NBPS. The generator set shall start, accelerate to rated speed and voltage, then stopped without closing the generator breaker. This cycle shall be repeated three times.

5.18 **No Break Power Supply Test:** This test shall be accomplished with the engine, LOCOP generator and voltage regulator-exciter connected. The test sequence and data recorded shall be in accordance with Table A-5. The Seller may perform additional procedures to test NBPS protection features not covered in Table A-5. Engine speed and individual outputs shall be continuously recorded. Testing shall verify the following design features:

a. NBPS battery capacity is in accordance with design requirements.
b. NBPS output voltages do not exceed specified limits under various combinations of power sources and output loading.
c. Engine speed is not affected due to various combinations of power sources and battery state.
d. The individual input sources are adequate to support full load and battery charging.
e. The LOCOP operation is not affected due to various combinations of power sources and battery state.
f. Alarm contact operation of Table I, item 25 of the Purchase Specification.
g. No equipment damage due to any combinations of switch selection.
h. Functions and adequacy of the test points of the mimic for monitoring state of inputs, battery voltage and voltage of outputs.

5.19 **EMI Characteristics Test:** The speed control system, no break power supply as well as other electrical engine accessories shall be subjected to MIL-STD-461E tests CE102, CS101, CS114, RS101, RS103, RE101, RE102 for surface ship, metallic hull, below deck. In addition, the governor system shall be subject to MIL-STD-461C tests CS06 and RS02 (part 1 magnetic induction spike).

6.0 Inspections after first article tests

6.1 **Visual and Dimensional Evaluation**: Upon the completion of the endurance test as outlined in Appendix A, the engine running clearances shall be measured and recorded. The engine and its attached and unattached assemblies shall be disassembled, each piece shall be examined. Measurements taken prior to the conduct of the endurance tests (see Table A-4 of Appendix A) shall be taken again and compared to wear limits and tolerances supplied by the manufacturer. Special tools furnished for the examination shall be used during this examination. Additional inspections may be requested such as reassembly of a particular component or non destructive tests such as hydraulic or crack detection tests.

6.2 **Reassembly**: After the examination is completed, the engine shall be reassembled using all of the same hardware that was in the engine when it was disassembled. Software such as gaskets and "O"-rings that would normally be replaced when reassembling the engine will be replaced at this time. It is not the intent of this paragraph that the engine be refurbished, or the hardware be replaced. Any hardware replacement must be specifically approved by the Government. The engine shall successfully pass an operational 8-hour cycle at 100 percent load and 100 percent speed.

6.3 **Evaluation Criteria**: The failure of any component to meet the Seller's wear limits, published reusability criteria, or the evidence of cracks, cavitation pitting, scuffing, galling, fretting, or signs of stress or overheating shall be cause for the rejection of the engine. Failing of any tests required by the first article may be cause for rejection of the engine.

Table A-3

ENDURANCE TEST DATA DESCRIPTION

Item	Location	Temperature	Pressure
a	Lubricating Oil		
	Sump	X	X
	Cooler in	X	X
	Cooler out	X	X
	Strainer in		X
	Strainer out		X
	Filter (full flow) in		X
	Filter (full flow) out		X
b	Fuel		
	Supply pump in	X	X
	Supply pump out		X
	Filter in		X
	Filter out		X
c	Seawater		
	Supply	X	X
	Pump in	X	X
	Pump out	X	X
	Intercooler in	X	X
	Intercooler out	X	X
	Engine out		
d	Jacket water		
	Engine in	X	X
	Engine out	X	X
	Cooler in	X	X
	Cooler out		
e	Inlet air		
	Compressor in	X	X
	Compressor out	X	X
	Manifold	X	
f	Exhaust gas		
	Individual cylinders out	X	X
	Turbine in	X	
	Turbine out		
e	Miscellaneous		
	Crankcase vapor		X
	Torque (observed)		
	Torque (corrected)		
	Speed		
	Fuel mass flow		

Table A-4

ENGINE COMPONENT WEAR MEASUREMENTS LIST

Items	Engine Component	Measurement
a	Cylinder liner	Inner diameter (id)
b	Piston	Outer diameter (od)
	Pin bore	id
	Pin	od
	Ring	Gap, radial width, thickness
		Ring-to-groove clearance
c	Connecting rod	
	Piston pin bushing	id
	Bearing	Thickness
	(assembled and torqued)	id
d	Crankshaft	od
	Journal	Thickness
	Main bearing	id
	(assembled and torqued)	Thickness
	Carrier bearing	End-play
	Crankshaft (assembled)	
e	Valve	
	Seat	Runout
	Guide	id
	Stem	od
f	Rocker arm	
	Bushing	id
	Shaft	od
	Follower	od
	Roller	Thickness
	Solid	
g	Camshaft	
	Journal	od
	Lobe	Height
	Base circle	od
	Bearing	Thickness (or id if bushings pressed into
	Thrust bearing	block)
	Camshaft (assembled)	Thickness
		End-play
h	Geartrain	Backlash
i	Gears	End-play
	Bushing	id
j	Turbocharger	
	Shaft	Radial movement, axial end-play
k	Blower	
	Rotor-to-housing	Clearance
	Rotor-to-rotor	Clearance
	Rotor-to-endplate	Clearance
	Rotor	End-play

Table A-4 (Con't)

ENGINE COMPONENT WEAR MEASUREMENTS LIST

Items	Engine Component	Measurement
l	Injection	Opening pressure, spray pattern, flow, leakdown rate
m	Injection pump	Flow
n	Engine block deck	Flatness
o	Cylinder head	Flatness
p	Oil pan rail	Flatness

Note:

1/ The Government and Seller shall coordinate to determine what engine component wear limit measurements are taken.

Appendix B
Production Engine Conformance Testing

1. General

After successful completion of the first article inspection and testing of the first engine, each production diesel engine thereafter shall be tested in the presence of the Government as per the quality conformance inspection and tests specified in this appendix. The manufacturer is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements. The engine supplier shall notify the Government in writing of each engine production test schedule. During conformance testing, the engine shall be subjected to the operating conditions specified in the purchase specification unless otherwise specified.

2. Quality conformance inspection and tests

2.1 **Emergency Shutdown:** The emergency shutdown device specified by the purchase Specification shall be operated with the engine stopped and with the engine operational. The emergency shutdown device shall be actuated while the engine is operational as follows:

a. Once with the engine operating at no load and at a speed that is 10 percent greater than rated speed or a simulation thereof.
Once with the engine operating at rated speed and full load

2.2 **Endurance Cycle:** One standard 8-hour endurance cycle composed as specified in Table A-1 of Appendix A, with the exception that 100-percent load shall be substituted for 110-percent load. Measurements of monitored parameters specified by the manufacturer shall be made at intervals specified by the first article test requirements in Appendix A. The operational data corresponding to each of the specified test load conditions shall be determined and all results compiled by the engine manufacturer. In each case all measurements conducted at the various load points shall be carried out at steady operating conditions. The readings for 110 percent power at rated speed shall be taken twice at an interval of at least 30 minutes. Lubricating oil samples shall be collected before and after the cycle and analyzed as specified in the first article inspection. Exhaust smoke emissions shall be measured using the methods specified for the first article inspection at each operating point of the standard 8-hour endurance cycle.

2.3 **Alarm Activation:** Response of each of the following alarm switch setpoints shall be tested:

a) Low lubricating oil pressure
b) High lubricating oil temperature from engine
c) High inlet manifold air temperature
d) High jacket water outlet temperature
e) High crankcase pressure

3.0 Test acceptance criteria

The production engine performance test will be considered successful when the following conditions are satisfied:

a. All test requirements specified in section 2.0 are met.
b. Any additional testing resulting form any forced shutdown, component replacement, or abnormal condition has been successfully completed.
c. All lube oil analyses are acceptable to the Government.
d. Engine condition as determined by the inspection following testing is acceptable to the Government.
e. Modifications developed as a result of testing and modifications developed as a result of final engine inspections shall be proven effective by means of a validation program acceptable to the Government.
f. Test report delivered from the Seller is fully acceptable to the Government.